EFFECTS OF PULSE FLOWS ON JUVENILE CHINOOK MIGRATION IN THE STANISLAUS RIVER

1999 ANNUAL REPORT

Prepared for

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EXECUTIVE SUMMARY

In 1999, we continued to fish a rotary screw trap in the Stanislaus River near Oakdale, California (river mile (RM) 40.1) to examine the potential effects of flow on the growth and migration of juvenile chinook salmon. Our study addressed three objectives:

1. Estimate the number of chinook salmon migrating out of the Stanislaus River.

2. Determine the size and smolting characteristics of juvenile chinook and rainbow trout/steelhead migrating out of the river.
3. Identify factors that influence the timing of juvenile chinook migrating out of the river.

For the 1999 sampling period, we began fishing the trap on January 18 (earlier than in previous years) and continued through June 30. We calculated a daily outmigration index by dividing the daily catch of chinook by the predicted trap efficiency. Overall, we saw a much higher fry outmigration in 1999 than in previous years. Estimated chinook migration down the Stanislaus River past Oakdale included 1,198,144 fry, 368,363 parr and 102,493 smolts, for a season total of 1,669,000 chinook migrants from January 18 to June 2, 1999. Outmigration peaked on January 21 when an estimated 56,176 chinook fry migrated past the trap.

We caught a total of 28,254 juvenile chinook at the Oakdale site during the 1999 trapping period, with daily catches ranging from 3 to 984 fish. The trap was fished daily between January 18 and June 30 except for one day in January, two days in March (technical repair) and weekends from Memorial Day through June (high river traffic).

We estimated the number of chinook passing our trap each night based on predicted

trapping efficiency for each day of the sampling period. Between February 19 and June 2, we released 17 groups (15 natural, 2 hatchery) of juvenile chinook to evaluate trap efficiencies. All releases were made at night with flows ranging from 1,117 to 4,158 cfs. The percent of released fish recovered in the screw trap varied from 0.26% to 3.77%.

Besides the trap at Oakdale, we also fished two traps at Caswell State Park (RM 8.6) under contract with the U.S. Fish and Wildlife Service (USFWS) to estimate the number of juvenile chinook migrating out of the lower Stanislaus River. Overall, in 1999 more fish were estimated to have passed the Oakdale trap (1,669,000 chinook) than the Caswell trap (1,321,042 chinook). Again, as at Oakdale, most of the chinook migrants, by far, were fry. Smolts and fry were only slightly less at Caswell than Oakdale, but 275,748 less parr were estimated to have passed Caswell compared to Oakdale. Most parr that pasted Oakdale may have reared to the smolt stage before passing Caswell, but survival must have been low, because there were also fewer smolts passing Caswell than Oakdale.

The mean lengths of juvenile chinook trapped at Oakdale increased gradually over the course of sampling, ranging from about 35 mm in mid-January to about 90 mm in late June. This gradual increase in mean length over time resembled the pattern seen in 1996, 1997 and 1998. However, while fish recaptured at Caswell in past years exhibited similar mean lengths as when captured at Oakdale—suggesting a quick migration through the Stanislaus—this pattern changed in 1999. There was a noticeable difference in mean length between the two sites beginning in March 1999 when the fish reached the parr stage. The largest difference occurred in mid-April when the fish reached approximately 60 mm in length. This suggests that fish were either stopping to rear or there was size selective mortality between Oakdale and Caswell.

We also examined relationships between changes in environmental conditions and chinook movement in 1999. We found that peak fry outmigration coincided with increases in flow in January, but not in February when peak passage occurred during periods of increased and decreased flows. Fry outmigration dropped quickly in mid-March when flows declined from over 4,000 cfs to less than 2,000 cfs. Flows in the river remained more stable from March through June when most smolt and parr outmigration occurred. These results suggest that flow increases probably encourage fry migration, but have less of an impact on smolts. We also found a potential relationship between fry movement and turbidity. In 1999, fry outmigration peaks during January and February occurred when turbidity levels were high. We recorded the highest outmigration for the sampling period on January 21, the day after turbidity jumped to 25 NTU's. We do not know how many fry migrated past the site on January 20 as our trap was not operating. Turbidity increases also corresponded with some peaks in parr and smolt outmigration, but not consistently. During the study, water temperatures at Oakdale gradually increased from near 46º F at the start of sampling to 57º F in June. Fluctuations in chinook migration did not appear to coincide with temperature changes.

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INTRODUCTION

Historically, the Central Valley drainage of California produced immense numbers of chinook salmon (*Oncorhynchus tshawytscha*). Runs of up to 30,000 fall chinook once returned to the Stanislaus River. Spawner escapements probably dropped as commercial fisheries expanded around the turn of the century, with annual catches of chinook reaching 4-10 million pounds. Other developments in the basin early in the century intensified the run's decline. Stanislaus River chinook were affected by stream blockage and degradation from mining practices, and by the reduction of salmon habitat and streamflows by dams and water diversions (Yoshiyama et al. 1998).

In recent years, annual returns of chinook salmon to the Stanislaus River have generally ranged from 2,000 to 6,000 fish. The run is stable, but below its historical level. Conditions in the basin have improved over the years, but are still believed to affect chinook populations. Studies initiated in recent years are providing new information about chinook production and migration in the Stanislaus River, and how they may be influenced by environmental factors, such as changes in flow, temperature, and turbidity. A better understanding of the chinook population, and how these and other factors affect them, will help us manage the river system more effectively for the benefit of chinook and the public.

STUDY BACKGROUND

In 1993, the South San Joaquin and Oakdale irrigation districts contracted with S.P. Cramer and Associates (SPCA) to examine the effects of different flows on juvenile chinook migration and growth in the Stanislaus River. The study, conducted by SPCA, is a joint effort between the irrigation districts, the California Department of Fish and Game (CDFG), and the U.S. Fish and Wildlife Service (USFWS).

In the spring of 1993, SPCA initiated a juvenile chinook monitoring program on the Stanislaus River. Since then, fish have been sampled each year near Oakdale (RM 40.1) and Caswell State Park (Caswell) (RM 8.6). Target species include fall-run chinook salmon and rainbow trout/steelhead (Table 1).

Table 1. Date, location and number of rotary screw traps operated in the Stanislaus River, 1993 - 1999.

Year	Trap Location	Number of Traps	Start Date	End Date	Flow-Year Type
1993	Oakdale	1	Apr 21	Jun 29	Low
1994	Caswell	1	Apr 23	May 26	Low
1995	Oakdale	1	Mar 18	Jul 1	Low
1995	Caswell	2	Mar 27	May 26	Low
1996	Oakdale	2	Feb 1	Jun 8	High
1996	Caswell	2	Feb 5	Jul 2	High
1997	Caswell	2	Mar 19	Jun 27	High
1998	Oakdale	1	Jan 26	Jul 15	High
1998	Caswell	2	Jan 8	Jul 16	High
1999	Oakdale	1	Jan 17	Jun 30	Med
1999	Caswell	2	Jan 17	Jun 30	Med

In the spring of 1993, SPCA biologists began fishing a rotary screw trap in the Stanislaus River near Oakdale to index the migration timing and abundance of outmigrating juvenile chinook during large manipulations in river flow. The trap fished from April 21 to June 29. Catches in the trap during this period suggested that outmigration peaked for only 1-4 days, when flows in the Stanislaus River increased from 400 cfs to 1,400 cfs about one week after the trap was installed on April 21 (Cramer and Demko 1993). The pattern of daily outmigrant abundance recorded before, during and after the sustained pulse flow events suggested that the stimulant effect of flow on chinook migration lasted only a few days and affected only a small portion of the population. The analysis did not indicate that sustained high flows "flushed" juvenile chinook out of the river.

In 1994, the CDFG operated one screw trap near the mouth of the Stanislaus River at Caswell State Park from April 23 to May 26. Daily catches ranged from zero to 75 juvenile chinook (Loudermilk et al. 1995). Catches were highest following the first pulse in flow (late April) and, as in 1993, dropped off dramatically within a few days. A second brief increase in catch occurred in late May after another increase in flow.

In 1995, SPCA continued the study, fishing one screw trap at the site near Oakdale where the trap was fished in 1993. The trap operated from March 18 to July 1. Sampling in 1995 showed that pulse flows did have a stimulant effect on juvenile chinook, but the effect was short, generally lasting only a few days (Demko and Cramer 1995). Further, pulse flows did not flush juvenile chinook out of the river.

SPCA also conducted mark-recapture tests with natural migrants and hatchery chinook in 1995 to estimate survival from Knights Ferry to Oakdale (14.2 miles). Estimated survival of natural migrants to the Oakdale trap varied from 32.4% to 66.7%, and was higher for larger fish (Demko and Cramer 1995). An estimated 4.7% and 8.6% of the fish from the two hatchery groups survived during the test.

In 1996, SPCA fished two screw traps at Caswell and one at Oakdale. Sampling began earlier, with the goal of estimating the total number of juvenile chinook outmigrants. However, when sampling began at Oakdale and Caswell in early February, the fry were already migrating. During the study, SPCA biologists found that the estimated abundance of juvenile chinook at the Oakdale and Caswell sites differed significantly, suggesting that juvenile chinook may encounter high mortality in the 31.5 miles between the Oakdale and

Caswell sites (Demko and Cramer 1997).

In 1997, SPCA continued to fish two rotary screw traps at Caswell. No sampling occurred at Oakdale due to high flows. High flows also delayed sampling at Caswell until mid-March (Demko and Cramer 1998).

In 1998, SPCA fished the Oakdale trap at the same location as in 1993, 1995, and 1996. The trap was installed on January 23, but final positioning was delayed by high flows. Sampling began January 26 and continued through July 15. During the season, fry outmigration peaked in mid-February and smolt outmigration peaked in early May. Overall, an estimated 598,873 chinook (417,185 fry, 60,041 parr, and 121,647 smolts) passed the Oakdale trap area between January 27 and July 15 (Demko et al. 1999).

SCOPE OF PRESENT WORK

The 1999 study continued to examine the effects of flows on juvenile chinook migration and growth in the Stanislaus River. Our work addressed three objectives:

1. Estimate the number of chinook salmon migrating out of the Stanislaus River.
2. Determine the size and smolting characteristics of juvenile chinook and rainbow trout/steelhead migrating out of the river.
3. Identify factors that influence the timing of juvenile chinook migrating out of the river.

Besides the Oakdale trap, SPCA also operates two traps near Caswell State Park under contract to the USFWS (Demko et al. 1999). Although the projects are under separate contracts with separate research objectives, much of the data collected at the lower river

Caswell site complements work conducted under this contract. Relevant information from the study is presented and discussed in this report.

DESCRIPTION OF STUDY AREA

The Stanislaus River begins on the western slopes of the Sierra Nevada's and flows southwest to the confluence with the San Joaquin River on the floor of the Central Valley (Figure 1). The San Joaquin River flows north, joining the Sacramento River in the Sacramento-San Joaquin Delta. The Stanislaus River is dammed at several locations for flood control, power generation and water supply. Water uses include irrigation and municipal needs, and recreational activities and water quality control.

Goodwin Dam, 58.4 river miles upstream from the San Joaquin River confluence, blocks the upstream migration of adult chinook. Most chinook spawning occurs upstream of the town of Riverbank (RM 34) to Goodwin Dam (RM 58.4).

Throughout this report we reference river miles on the Stanislaus River. River miles were determined with a map wheel and 7.5 minute series USGS quadrangle maps, (Knights Ferry, 1987 and Oakdale, 1987). The estimated river miles of our trapping and release locations are as follows:

Knights Ferry release site	RM 54.3
Orange Blossom Bridge	RM 46.9
Highway 120/108 release site	RM 41.2
Pipe release site	RM 40.6
Oakdale trapping location	RM 40.1
Caswell trapping location	RM 8.6

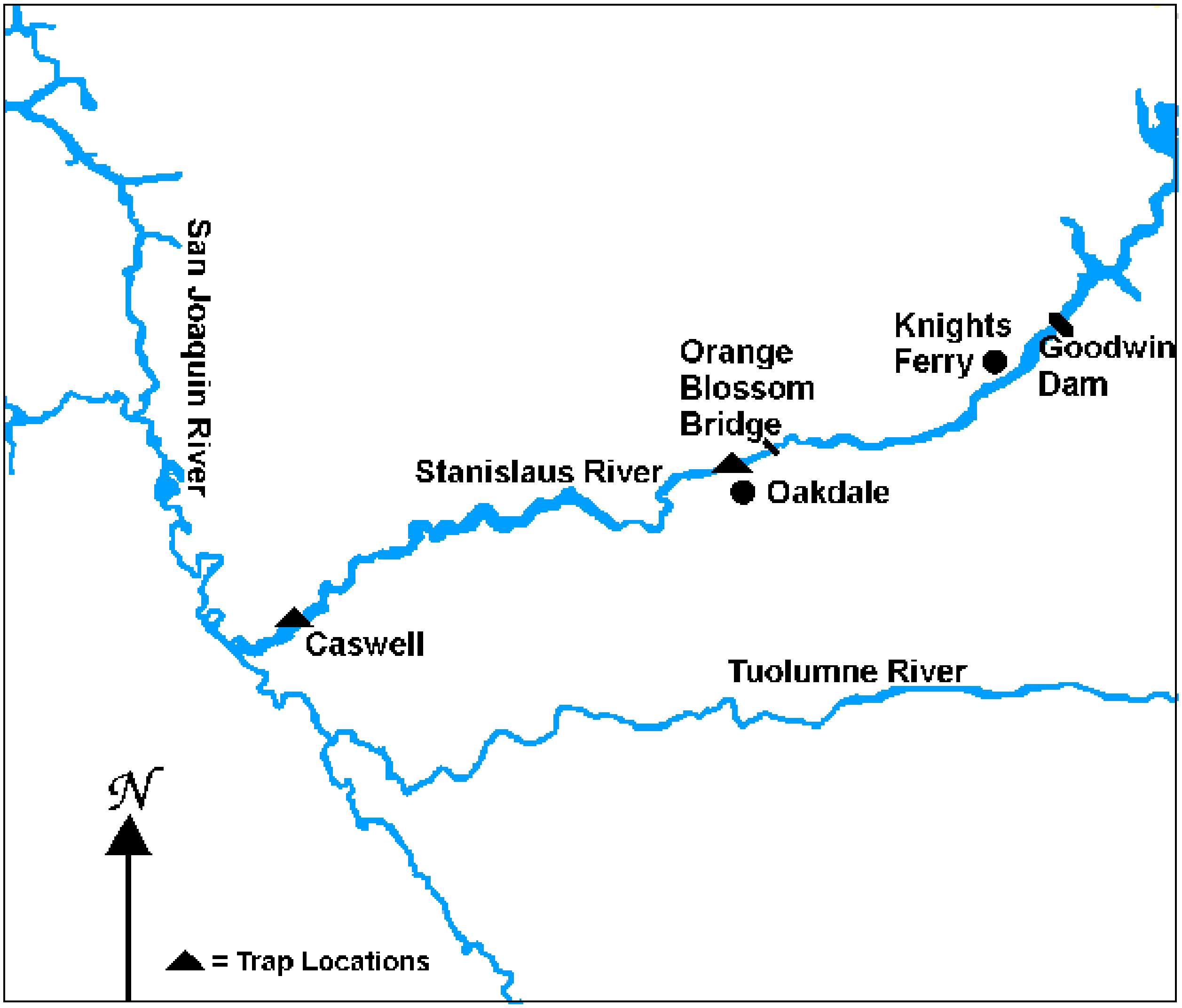

Figure 1. Location map of San Joaquin Basin and Stanislaus River.

METHODS

JUVENILE OUTMIGRANT MONITORING

Trapping Site

To capture juvenile chinook as they migrated downstream, we fished a rotary screw trap in the mainstem of the Stanislaus River near the Oakdale Recreation Area, about three miles west of the town of Oakdale, California. This trap site (RM 40.1) was chosen because it offered the farthest downstream location with adequate water velocities for efficient trap operation at low river flows. Fast water velocities increase the rotation speed of the trap, as well as its capture efficiency. The site lies downstream from most chinook spawning and juvenile rearing and was also fished in 1993, 1995, 1996 and 1998.

The trap, a funnel-shaped cone suspended between two pontoons, was manufactured by E.G. Solutions in Eugene, Oregon (Figure 2). It was positioned in the current with the 8-foot wide funnel mouth facing upstream. Water entering the funnel would strike the internal screw core, causing the funnel to rotate. As the funnel rotated, fish were trapped in pockets of water and forced rearward into a livebox where they were caught. The trap was held in a static position in the main current by a 3/8 inch cable suspended across the river about 40 feet above the water surface. Cables fastened to the front of each pontoon were attached to the overhead cable. This design held the trap in position while still providing adequate space for recreational river users to pass the trap safely.

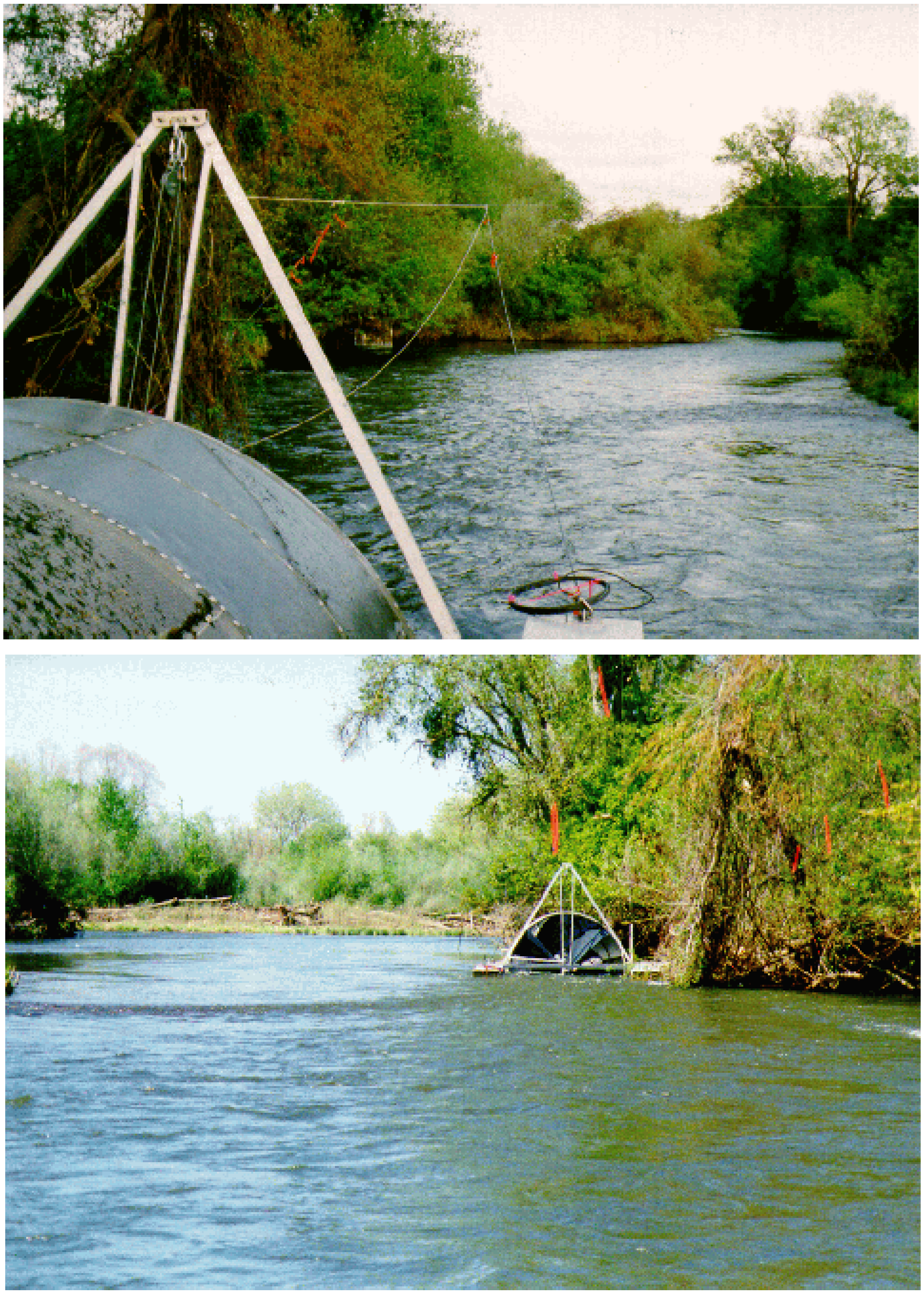

Figure 2. Photographs of the rotary screw trap.

Trap Monitoring

We began fishing the Oakdale screw trap on January 17 and conducted the first sampling on January 18 (Figure 3). Monitoring continued until June 30. No catch was recorded for January 20, March 19, March 24 or April 21 due to either high flows or trap malfunction. In addition, we did not fish the trap on the weekends of May 29-31, June 12-13, June 19-20 or June 26-27, because of safety concerns for the many recreational river users, particularly rafters, that float through the Oakdale vicinity beginning in late spring. On those weekends, we raised the trap's rotating cone from the water and pulled the trap closer to the banks, creating a wider passageway on the river.

Between January 17 and June 30, we fished the trap 24 hours per day seven days per week, except during times when the cone was raised because of high flows, trap malfunction or safety concerns. The trap was checked and cleaned daily to prevent buildup on or in the cone where it could impair trap rotation. We also removed debris that accumulated against the trap and in the livebox. The debris load in the livebox was estimated and recorded whenever the trap was checked. During high winds, heavy rains or significant changes in flow—which usually increased the debris load—we checked the trap in the morning and at dusk, thus ensuring that the captured fish were not at risk due to a debris overload, and that the cone was operating properly. We also checked the trap several times daily during times of high turbid flows and when we had recently released marked fish to see if fish were indeed being captured during the day. Following efficiency releases, the trap was monitored every hour or two, depending on the amount of debris buildup and the number of fish being captured.

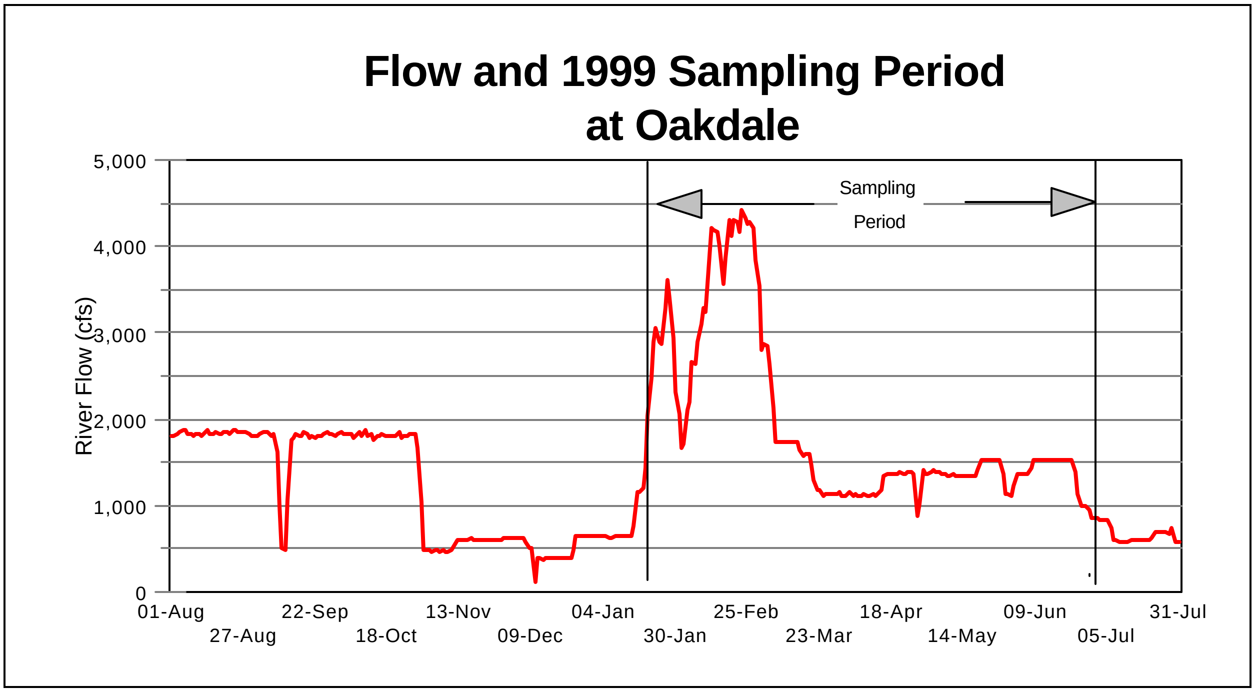

Figure 3. Flows during outmigration sampling period in the Stanislaus River, 1999.

During natural freshets, fish would accumulate in the livebox fairly rapidly and the trap was monitored every two to three hours, reducing the chance of mortality to juvenile chinook. We created areas for fish refuge in the livebox by placing a metal grate propped up by cinder blocks near the rear of the livebox. This grate helped separate the larger, more dangerous debris from other areas of the box, while the holes in the cinder blocks added stability and additional cover. This partial barrier also helped to reduce the current in the rear of the livebox, thereby reducing stress on the fish it contained.

Each morning we removed the contents of each livebox and identified and counted all fish captured. A random sample of 50 chinook and 20 of each other species were measured and their lengths recorded in millimeters. We tried to weigh a total of 50 fish each week. If 50 fish could not be weighed in one day, or if 50 fish were not captured in one day, then fish were weighed on consecutive days until the goal was met. A hand-held spring scale (Pesola®) of the appropriate size was used to weigh the fish. We also measured all rainbow/steelhead and all yearling chinook. The traps were cleaned after all fish were recorded.

Scale samples were taken daily from a few chinook, which were randomly selected from the livebox each week after they reached the appropriate size and stage of development. Scale samples were also taken from most of the yearling chinook and rainbow/steelhead captured. A small knife was used to scrape away a few scales in the area just posterior to the dorsal fin and above the lateral line. Each sample was placed in a separate labeled envelope with the length of the fish, date, time and smolt index recorded on the outside.

Smolt Index Rating

We also checked each chinook and rainbow trout/steelhead for smolting characteristics, using a different scale for each species. Smolting chinook appearance was rated on a scale of 1 to 3, with 1 an obvious parr (highly visible parr marks) and 3 an obvious smolt (silvery appearance, easily shed scales, blackened fin tips). Rainbow trout/steelhead were rated on a scale provided by the Interagency Ecological Program (IEP) Steelhead Project Work Team. This steelhead smolting scale rates the fish on a range of 1 through 5, with 1 being a yolk-sac fry, 2 a fry, 3 a parr, 4 a silvery parr and 5 an obvious smolt.

EXPERIMENTAL RELEASE GROUPS

Trap Efficiency Releases

Seventeen groups of fish were released from February 19 through June 2 to determine trap efficiencies (Table 2). Two of the release groups were hatchery-reared fish obtained from the Merced River Hatchery. One group of hatchery-reared fish, containing 367 fish, was released on June 1 and the other group, containing 394 fish, was released on June 2. These groups were marked at the hatchery using a panjet dye marking system, and then transported to the release site on the morning before the night of their release. The remaining 15 groups contained natural juvenile chinook, which were captured in the screw trap. Generally, we accumulated the fish over several days to have enough for a group. The first 3 groups of natural fish were marked by cold brand and the final 12 natural groups were marked by dye inoculation using a photonic marking system. One group of photonically-marked fish experienced substantial mortality after the marking procedure and their release, scheduled March 24, was voided. The number of fish in each group ranged from 193 to 579. All marked fish were released at dark.

Holding Facility and Transport Method

Fish were held in free standing net pens measuring 4 ft x 4 ft x 4 ft and 2 ft x 3 ft x 3 ft. The net pens consisted of 3/16 inch Delta mesh sewn onto frames constructed of one half-inch diameter PVC pipe. The net pens were placed inside a submerged chain-link style dog kennel, which was constructed in the river to protect fish from predators and human disturbances. The kennel was located near the trap in an area of low velocity.

Table 2. Date, stock, location, time, number of fish released and river flow for trap efficiency, migration rate and survival tests in the Stanislaus River during 1999.

Release Code	Date of Release	Mark Type	Fish Stock	Adjusted # Released	Total # Recaptured	% Recap.	Mean at Release	Mean at Recapture	Avg. Flow at OBB
O1	19-Feb-99	Brand	Natural	326	10	3.07%	34.2	33.9	4,129
O2	22-Feb-99	Brand	Natural	316	6	1.90%	35.8	36.0	4,158
O3	01-Mar-99	Brand	Natural	193	5	2.59%	35.2	34.1	3,535
O4	05-Mar-99	Photonic	Natural	519	4	0.77%	35.8	36.5	2,641
O5	10-Mar-99	Photonic	Natural	344	5	1.45%	36.5	35.4	1,734
O6	12-Mar-99	Photonic	Natural	579	15	2.59%	36.8	39.5	1,727
O7	16-Mar-99	Photonic	Natural	384	1	0.26%	37.9	46.0	1,643
O8	24-Mar-99	Photonic	Natural	VOID	VOID	VOID	VOID	VOID	VOID
O9	30-Mar-99	Photonic	Natural	391	11	2.81%	49.6	57.5	1,146
O10	06-Apr-99	Photonic	Natural	356	10	2.81%	60.4	56.3	1,117
O11	13-Apr-99	Photonic	Natural	442	5	1.13%	61.1	52.4	1,129
O12	01-May-99	Photonic	Natural	398	15	3.77%	71.3	69.8	1,364
O13	08-May-99	Photonic	Natural	378	5	1.32%	72.4	72.4	1,348
O14	12-May-99	Photonic	Natural	379	3	0.79%	76.1	80.0	1,339
O15	20-May-99	Photonic	Natural	399	2	0.50%	73.6	76.5	1,534
O16	01-Jun-99	Panjet	Hatchery	367	1	0.27%	82.9	80.0	1,229
O17	02-Jun-99	Panjet	Hatchery	394	5	1.27%	86.3	86.6	1,365

Before release, the fish were transported to the efficiency release site in 20-gallon insulated coolers. Between 75 and 150 fish were placed in each cooler and transported a half-mile upstream from the trap for trap efficiency tests. The fish remained in the cooler for 15 to 45 minutes, depending on the circumstances. We always carried an aerator, but never needed to deliver oxygen to the coolers during transport.

Marking Procedure

Two methods, cold-brand and dye inoculation, were used to mark juvenile chinook. All fish were anesthetized with MS-222 (Schoettger and Steucke 1970) before the appropriate mark was applied. Fish in three of the release groups were cold-branded by freezing a branding stick in a thermos of liquid nitrogen. The fish were then laid on a flat surface and the appropriate mark was applied by placing the tip of the branding tool against the front/rear, right/left section of the body of the fish. Minimal pressure was applied for approximately two seconds and each fish received only one mark.

Fish in two release groups were dye-inoculated by placing the tip of a MadaJet marker against the caudal (top or bottom lobe), dorsal or anal fin (Hart and Pitcher 1969). Minimal pressure was applied as dye was injected into the fin rays. One mark was applied to each fish, and all fish in a group received the same mark. The mark's location was varied between groups so each group could be uniquely identified.

A photonic marking system was used for marking most of the release groups because of the high quality of marks and the ability to use the marking equipment in rapid succession. These markers were used in the same way as the Madajets. Several different photonic dye colors were used to differentiate the groups, including photonic pink, photonic blue, photonic orange, photonic violet and, photonic green. The dyes, purchased from NewWest Technologies of Santa Rosa, California, were chosen because of their known ability to provide a highly visible, long-lasting mark.

Pre-release Sampling

Marked fish were sampled for mean length and mark retention. Fifty fish were randomly selected from each distinctly marked group and anesthetized. Mark retention was rated as present or absent, and, if any of the 50 fish were found to have no mark, an additional 50 fish were sampled. The proportion of fish found to have clear marks in each group was used to estimate the actual number of marked fish released by the expression:

*number released = proportion mark retention * number in group*

Release Procedure

To estimate trapping efficiency, the fish were released a half-mile above the trap, where the main Oakdale waste pipe crosses over the Stanislaus River. Before release, the fish were placed in one to three coolers filled with water, depending on the size of the release group, and transported to the release site. We released the fish by placing a dip net into the cooler, scooping up about 10 fish and dipping the net into the river so they could swim away. After releasing a "net-full" of fish, we waited 30 seconds to 3 minutes before releasing another net-full of about 10 fish. The amount of time between releases varied depending on how fast the fish swam away after being released. Release time for the groups ranged from 15 to 45 minutes. This release procedure was similar to the one used in 1998, as the fish were released directly from coolers instead of being transferred to net pens for release as in 1996. All trap efficiency groups were released under total darkness in 1995, 1996, 1998 and 1999.

Developing the 1999 Capture Efficiency Model

We calculated the daily outmigration index by dividing the number of chinook captured at Oakdale each day by the predicted daily trap efficiency (proportion of released fish that were later recaptured):

$$Outmigration \quad Index = \frac{Count}{Efficiency}$$

To predict the efficiency for each passage day, the efficiency estimates were viewed as a response (dependent variable) to the predictor(s) (independent variables) measured each day the screw traps operated. Three predictor variables were explored: flow (f)(in cubic feet per second, cfs) measured at Orange Blossom Bridge, fish fork length (s)(in millimeters, mm), and turbidity (t)(in nephelometric turbidity units, ntu). Efficiency (e), the proportion of released fish trapped per release, was related to the predictor variables using the logistic relation:

$$efficiency\ (e) = \frac{1}{1 + \exp^{[-b(0)-b(f)\times f-b(s)\times s-b(t)\times t]}}$$

or, using the "logit" linear transform,

$$logit\ (e) = \ln\left[\frac{e}{1-e}\right] = b(0) + b(f)\times f + b(s)\times s + b(t)\times t + b(s)\times s$$

In the above equations "exp" is the exponential function, "ln" is the natural log, "b(0)" is a coefficient associated with the intercept[1], and b(f), b(s), and b(t) are partial logistic regression coefficients relating the logit transform of efficiency to the indicated predictor variables. We used the logistic model primarily because the predicted efficiency can never be less than zero and can never exceed one (100%). The logistic regression we used assumes that the underlying distribution of the number of captured fish is binomial when the model is accurate.

The predictor variables evaluated in this analysis were the same as in previous years, though many of the 1996 through 1998 measures differed from those used in the 1999 report. Previously, the length of sampled released fish, release-day flow, and release-day turbidity were used as the predictor variables. In 1999, the measures were:

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1 Intercept value = $1/\{1+\exp^{-b(0)}\}$ when f = s = t = 0.

Flow: The mean of release-day and recovery-day flows: We used the mean of release-day and recovery-day flows because releases were made in the evening of the release day and almost all were recovered by the following morning (recovery day). Therefore, the mean of the two days' flows was considered to be a better indicator of the flow during the recovery period then was the release-day flow. Overall, the predictor variable is the mean of the flows from the day of capture and from the day before recapture.

Fish size: Length of recovered fish was deemed a better measure than size of released fish because the predictor would be applied to captured fish. Thus, we used fish recovered in the trap for the analysis instead of released fish.

Turbidity: We decided to use recovery-day turbidities in the current analysis for all three years since turbidity levels were checked and recorded in the morning when the recovered fish were counted,

This missing-value-substitution method differed from the one used previously. For consistency, we used this method to recompute missing values of flow and turbidity from 1996, so some predictor variable values differ from those reported for passage in 1996 and 1998. The missing-value-substitution methods are detailed in the appendix.

To evaluate the effectiveness of each predictor variable (Table 3), we conducted an analysis of variation procedure. The analysis of variation was applied to the residual logistic-regression deviancies, which are analogous the residual sums of squares from least squares regression (refer to Appendix A.2).

Table 3. Predictor variables and efficiency response variable used to develop logistic efficiency predictor.

Release Date	Flows: Release Day	Flows: Recovery Day	Flows: Average	Recovery Length	Recovery-Day Turbidity	Efficiency (Proportion Recovered)	Adjusted Release Number
02/12/96	681	913	797	30.0	5.1	0.2838	969
03/22/96	3,413	3,010	3,212	43.6	3.1	0.0130	617
04/06/96	1,791	1,780	1,786	73.2	2.6	0.0900	500
04/06/96	1,791	1,780	1,786	71.9	2.6	0.0641	499
04/14/96	1,595	1,599	1,597	80.4	2.1	0.1010	198
04/22/96	1,673	1,668	1,671	86.9	3.0	0.1250	248
05/04/96	1,674	1,662	1,668	74.1	2.3	0.1316	547
05/26/96	921	955	938	78.0	2.4	0.2533	304
05/29/96	935	935	935	91.1	2.1	0.2387	507
03/02/98	3,508	2,967	3,238	35.6	4.1	0.0269	929
03/18/98	1,768	2,798	2,283	59.3	3.0	0.0564	479
04/06/98	1,561	1,822	1,692	69.0	2.5	0.0663	347
04/11/98	2,066	2,069	2,068	66.1	2.7	0.0595	168
05/02/98	1,972	2,008	1,990	79.5	8.1	0.0383	392
05/30/98	2,034	2,053	2,044	88.0	2.3	0.0760	250
05/30/98	2,034	2,053	2,044	98.5	2.3	0.0861	267
06/13/98	1,564	1,565	1,565	91.7	3.7	0.0479	146
06/13/98	1,564	1,565	1,565	104.8	3.7	0.0686	175
06/24/98	2,130	2,155	2,143	86.5	2.4	0.0741	81
06/24/98	2,130	2,155	2,143	89.5	2.4	0.0476	84
02/19/99	4,129	4,316	4,223	33.9	10.0	0.0307	326
02/22/99	4,158	4,432	4,295	36.0	2.2	0.0190	316
03/01/99	3,535	2,800	3,168	34.1	1.5	0.0259	193
03/05/99	2,641	2,135	2,388	36.5	1.9	0.0077	519
03/10/99	1,734	1,730	1,732	35.4	1.6	0.0145	344
03/12/99	1,727	1,724	1,726	39.5	1.4	0.0259	579
03/16/99	1,643	1,577	1,610	46.0	1.4	0.0026	384
03/30/99	1,146	1,116	1,131	57.5	1.4	0.0281	391
04/06/99	1,117	1,111	1,114	56.3	1.2	0.0281	356
04/13/99	1,129	1,169	1,149	52.4	3.3	0.0113	442
05/01/99	1,364	1,384	1,374	69.8	1.3	0.0377	398
05/08/99	1,348	1,348	1,348	72.4	1.7	0.0132	378
05/12/99	1,339	1,344	1,342	80.0	1.1	0.0079	379
05/20/99 **1**	1,534	1,533	1,534	76.5	1.5	0.0050	399
06/01/99	1,229	1,365	1,297	80.0	1.5	0.0027	367
06/02/99	1,365	1,369	1,367	86.6	2.4	0.0127	394

1 May 20, 1999 release omitted because of lethargic behavior of released fish

MONITORING ENVIRONMENTAL FACTORS

Flow Measurements

Daily flow data on the Stanislaus River was obtained from the California Data Exchange Center. All river flows cited in this report were measured at Orange Blossom Bridge by the U.S. Geological Survey. The flow data represent daily averages, so instantaneous flows during freshets were higher. Depth-velocity profiles were taken in front of the traps.

We used two methods to measure the velocity of water entering the traps. First, while checking the traps, we measured water velocity with a Global Flow Probe, manufactured by Global Water (Fair Oaks, CA). Second, we calculated an average daily trap rotation speed for each trap. To determine the average time per revolution for each trap, every morning we measured the time needed, in seconds, for each trap to make three contiguous revolutions.

River Temperature and Relative Turbidity

Daily water temperature at the trap site was measured with a mercury thermometer. In addition, we used Onset StowAway recording thermometers to record water temperature once per hour throughout the sampling season. These thermometers were installed at six sites on the Stanislaus between Goodwin and Caswell, including the Oakdale and Caswell trapping sites. Daily average temperature was derived by averaging the 24-hourly measurements.

We also measured turbidity each day using a LaMotte turbidity meter, Model 2008. A water sample was collected each morning and later tested at the field station. Turbidity was recorded in Nephelometric Turbidity Units (NTU's).

RELATED MONITORING AT THE CASWELL TRAPPING SITE

Besides our screw trap near Oakdale, two screw traps were fished near the mouth of the Stanislaus River, by Caswell State Park (RM 8.6), under contract to the USFWS. The traps were operated from January 8 to July 16 to index juvenile chinook abundance. All data was collected according to criteria established by the USFWS.

RESULTS

OBJECTIVE 1: ESTIMATE THE NUMBER OF CHINOOK SALMON MIGRATING OUT OF THE STANISLAUS RIVER IN 1999.

TRAP CATCHES OF CHINOOK

Daily catches of juvenile chinook between January 18 and June 30 ranged from 3 to 984 fish, and totaled 28,254 fish (Figure 4). The trap was fished daily during this period, except for one day in January, two days in March (technical repairs) and weekends from Memorial Day through June (high river traffic). We do not know whether or not a significant number of fish outmigrated before the trap was installed, but our degree day analysis indicates that fry emergence started about 10 days before the onset of sampling.

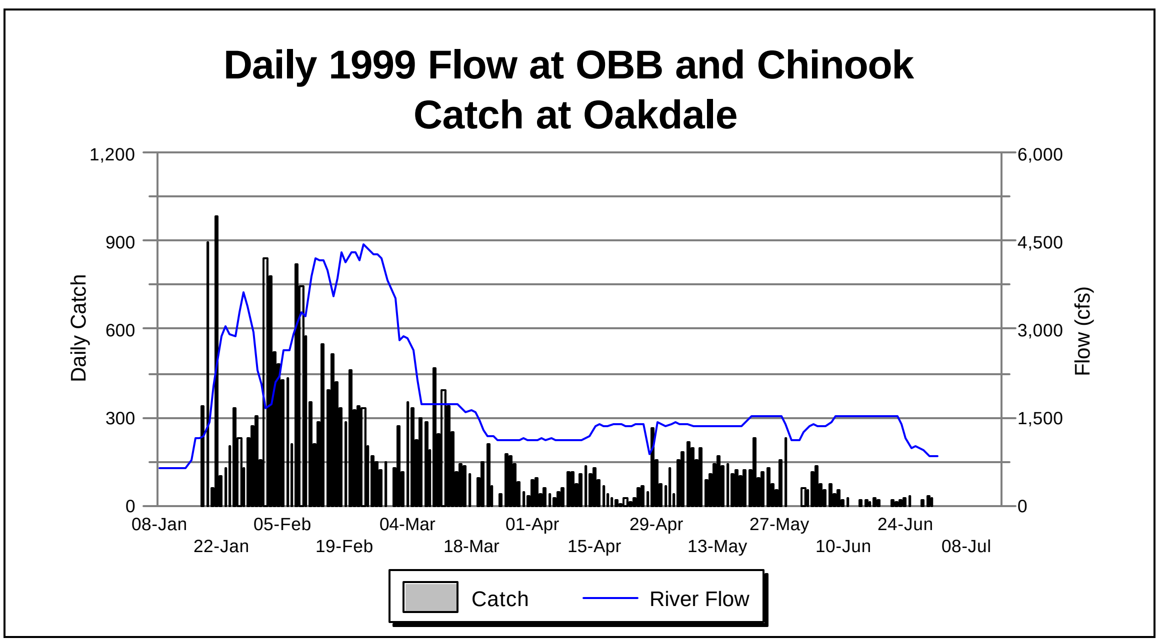


Figure 4. Daily catches of juvenile chinook and Stanislaus River flow, 1999.

TRAP EFFICIENCY

Between February 19 and June 2, we released 15 groups of marked natural chinook and 2 groups of marked hatchery chinook to estimate trapping efficiency (Table 4). All releases were made at night and flows for the period varied between release groups from 1,117 to 4,158 cfs. Capture rates of marked fish ranged from 0.26% to 3.77%.

Table 4. Release data for all fish released for trap efficiency tests in 1999.

Release Code	Date of Release	Mark Type	Fish Stock	Adjusted # Released	Total # Recaptured	% Recap.	Mean at Release	Mean at Recapture	Avg. Flow at OBB
O1	19-Feb-99	Brand	Natural	326	10	3.07%	34.2	33.9	4,129
O2	22-Feb-99	Brand	Natural	316	6	1.90%	35.8	36.0	4,158
O3	01-Mar-99	Brand	Natural	193	5	2.59%	35.2	34.1	3,535
O4	05-Mar-99	Photonic	Natural	519	4	0.77%	35.8	36.5	2,641
O5	10-Mar-99	Photonic	Natural	344	5	1.45%	36.5	35.4	1,734
O6	12-Mar-99	Photonic	Natural	579	15	2.59%	36.8	39.5	1,727
O7	16-Mar-99	Photonic	Natural	384	1	0.26%	37.9	46.0	1,643
O8	24-Mar-99	Photonic	Natural	VOID	VOID	VOID	VOID	VOID	VOID
O9	30-Mar-99	Photonic	Natural	391	11	2.81%	49.6	57.5	1,146
O10	06-Apr-99	Photonic	Natural	356	10	2.81%	60.4	56.3	1,117
O11	13-Apr-99	Photonic	Natural	442	5	1.13%	61.1	52.4	1,129
O12	01-May-99	Photonic	Natural	398	15	3.77%	71.3	69.8	1,364
O13	08-May-99	Photonic	Natural	378	5	1.32%	72.4	72.4	1,348
O14	12-May-99	Photonic	Natural	379	3	0.79%	76.1	80.0	1,339
O15	20-May-99	Photonic	Natural	399	2	0.50%	73.6	76.5	1,534
O16	01-Jun-99	Panjet	Hatchery	367	1	0.27%	82.9	80.0	1,229
O17	02-Jun-99	Panjet	Hatchery	394	5	1.27%	86.3	86.6	1,365

Early in the season, we caught enough naturally migrating fry to justify marking these fish for additional releases to test trap efficiency. However, as requested by CDFG, we limited our releases of naturally produced fish to approximately once per week. The limited number of releases prevented us from making any location or day-night comparisons as in past years. However, previous trap efficiency results suggest that location does not play a significant role, and that day releases are ineffective in accurately determining trap efficiency.

Size Selectivity of Screw Trap

Our examinations of mean length before release and at recapture showed that the mean size of recaptured chinook did not differ significantly from the mean size of fish at release (see Table 4 and Figure 5). This suggests that trap efficiency does not change with fish size. The predictive method used to determine if the traps caught more of the small fish or large fish from the trap efficiency release groups assumed that the trapped fish would represent all fish passing the trap.

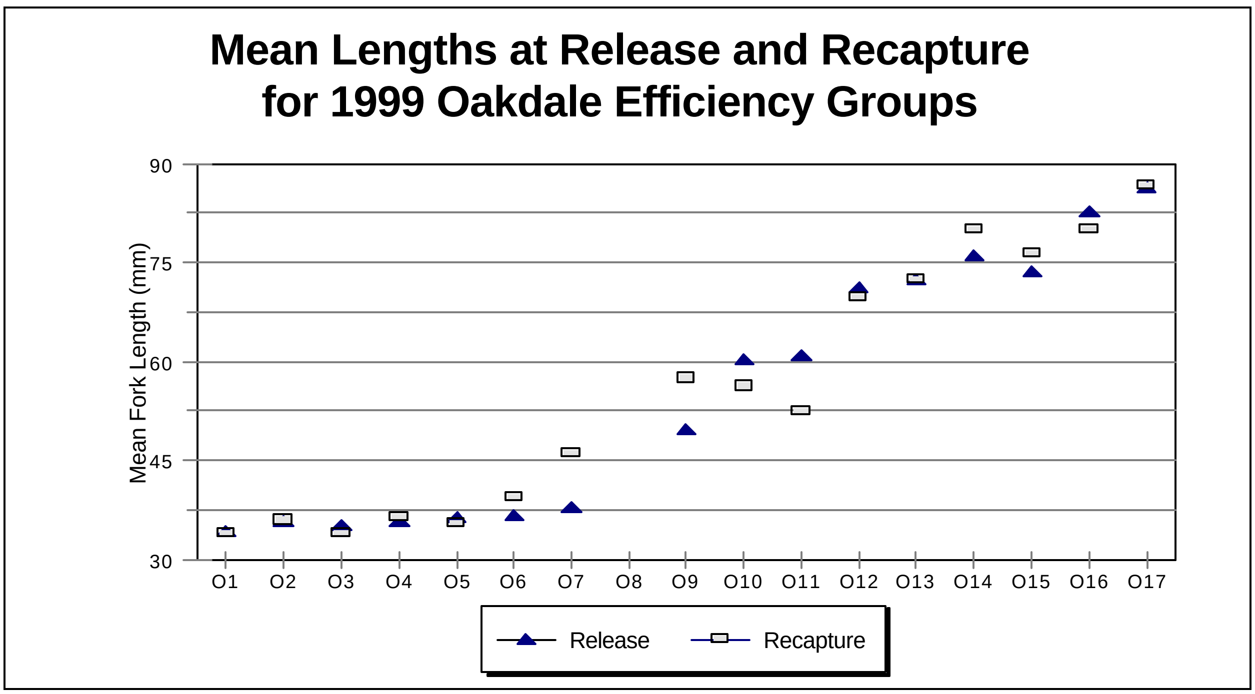


Figure 5. Mean lengths at release and recapture for all marked fish released in 1999.

1999 Trap Capture Efficiency

Daily counts from the two screw traps were available from February 1 to June 8, 1996, from January 26 to July 15, 1998, and from January 18 to June 30, 1999 (referred to as passage days). On 32 days during these monitoring periods for the three years combined, we made 36 uniquely marked night releases. The fish were released at a fixed location upstream from the Oakdale screw trap to estimate trap efficiency.

Trap efficiency releases were made in the same location, using the same release procedures, and within similar flow ranges in all years. For 1996 and 1998, differences within and between years did not vary substantially or significantly (details given below). As a result, we could combine our analysis for these years and better estimate the efficiency rates for times when tests were not conducted. However, since we used different measures as the predictor variables in 1999 (see Methods, Page ...), our data for 1999 was evaluated separately.

In 1999, we analyzed our variable procedure to determine the effectiveness of each predictor variable (flow, fish size and turbidity). This analysis showed that none of the variables significantly or substantially increased the precision, and the predictor used was simply the weighted mean of the efficiency estimates (the weights being the number of fish released). The 1999 mean deviance was much greater than in 1996 and 1998, as would be expected from binomial distribution. Thus, the precision of the 1999 predictor was poorer than for the 1996 and 1998 predictors. The coefficients for the selected 1996, 1998, and 1999 models are presented in the Appendix, Table 2. A t-test was used to test the coefficients in Table 2. While the t-test may not have been the most appropriate tool for examining the coefficients, since the estimated efficiencies are not expected to be normally distributed, it was used since the asymptotic z-test would have been too liberal.

ABUNDANCE OF CHINOOK OUTMIGRANTS

Outmigration abundance was cumulated over the dates given in Table 5 (page 30), which provides outmigration-index estimates of fry, fingerling, smolt, and total juveniles within years. These estimates were generated using a predicted daily efficiency (e) to expand the daily count (c) and obtain an estimated daily estimated outmigration index (o). The outmigration index estimate for a given day (o_i) is given in Equation 2.

Equation 2.

$$o_i = \frac{c_i}{e_i} = \frac{c_i}{\dfrac{1}{1+\exp[-b(0)-b(f)\,f_i - b(s)s_i - b(t')t'_i}}$$

$$= c_i * \{1+\exp[-b(0)-b(f)\,f_i - b(s)s_i - b(t')t'_i\,]\}$$

These new estimates differ from those presented in the 1998 report because of data modifications. The confidence intervals presented are generally narrower than in previous reports. This is because the previous confidence interval estimate was based, in part, on the approximate variance of a ratio (the ratio estimate being given in the first line of Equation 2), which turned out to be conservative (larger than it should). The variance estimate has been improved by using an unbiased estimate of the variance of a product (the product being given in the second line of Equation 2). The methodology is detailed in the appendix.

Outmigrant abundance in 1999 was greatest on January 21 (Figure 6) when fish were still at the fry (< 45 mm) life stage. We estimate that 56,176 chinook fry migrated past the trap that night. The total number of 1,669,000 fish (95% CI 1,101,297-1,668,994) outmigrated during the season from January 18 to June 2, 1999 (see Figure 7, Table 5).

We revised our estimates of total chinook outmigrants for 1996 and 1998 to take into account the changed methodology. The 1996 estimate was previously reported as 279,618 outmigrants. The slight difference between this and the revised estimate of 302,276 outmigrants (95% CI 231,571-372,982) is solely attributable to the different method of computing missing values (i.e. flow, trap stoppage). The 1998 estimate increased from 599,050 to 979,754 outmigrants.

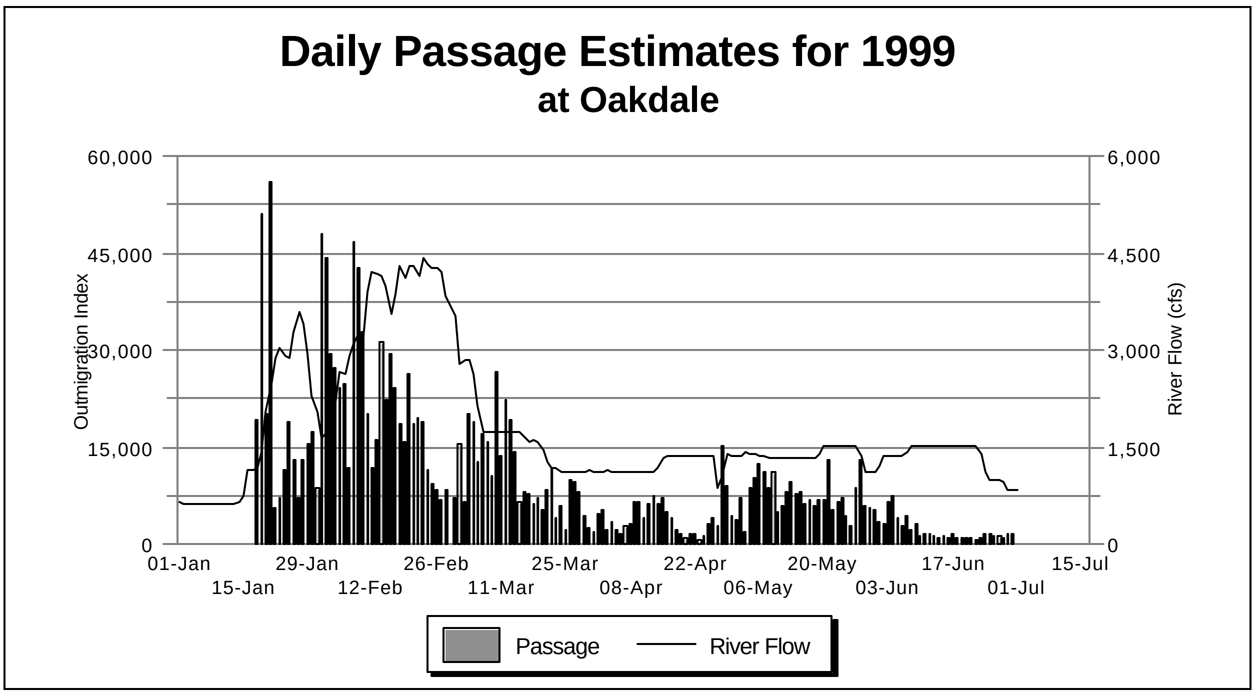


Figure 6. Daily abundance of outmigrant chinook and river flow.

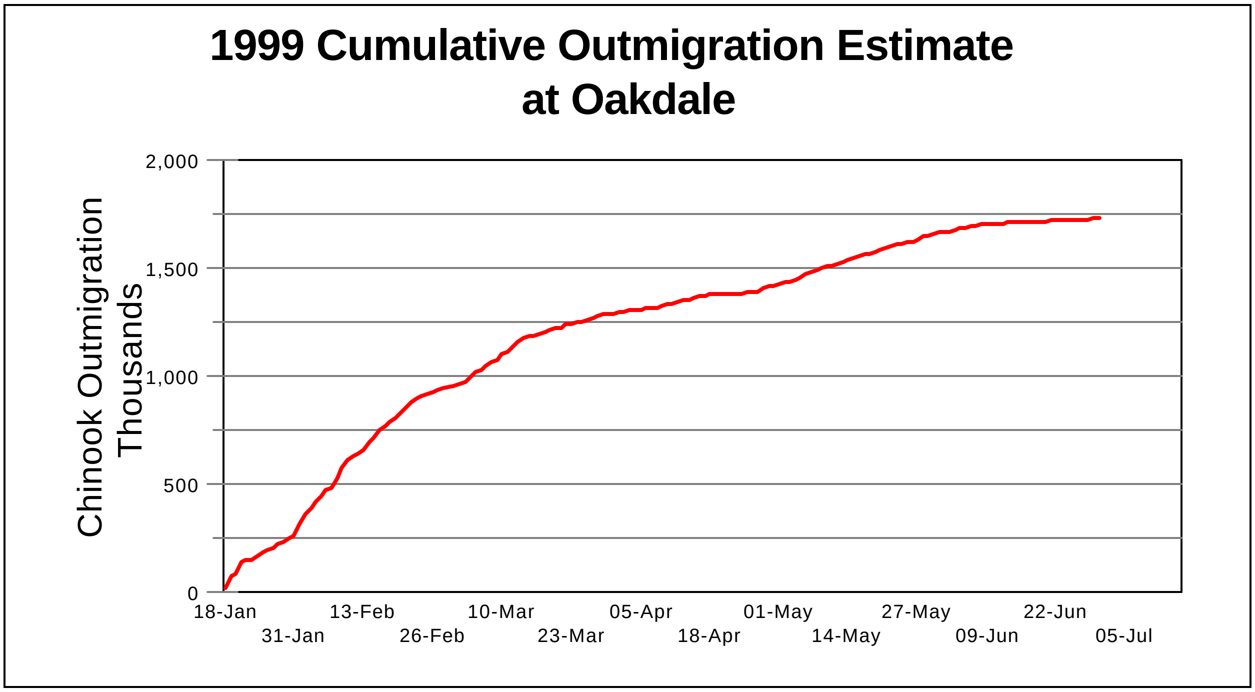


Figure 7. Cumulative outmigration index at Oakdale for 1999.

Of all years studied (1996, 1998 and 1999), our estimate of chinook subyearling abundance was greatest in 1999, totaling more than 1.6 million (UCL 2,236,702, LCL 1,101,297) and greatly exceeding the 1998 estimate of 979,754 chinook subyearlings. Although 95% confidence limits are large for each year's estimated chinook subyearling abundance, they do not overlap. Still, it is difficult to determine whether there is a difference between 1998 and 1999 since the traps were not installed at the same time. Although the traps were installed earlier in 1998 than in previous years, we suspect that a proportion of the fry outmigration was still not sampled. A large number of fish may have also passed during high flows in February 1998 when our traps were not functioning. Because of the differences in trapping periods, it is difficult to compare outmigration numbers among years.

OUTMIGRATION BY JUVENILE LIFE STAGE CLASSIFICATION

In past years we estimated total outmigration for each juvenile chinook life stage, where; fry < 45 mm; parr 45 mm to 80 mm; smolt > 80mm. Cut off dates for each life stage began when the daily mean lengths exceeded the previous stage for five of seven days; though the daily lengths of sampled fish over contiguous days can bounce above and below the values we used to separate the different stages. To address this, in 1999 we used an algorithm to establish dates separating fry from parr, and parr from smolts. When the number of continuous days that fish fall into the larger life-stage permanently exceeds the previous number of continuous days when the fish fall into the smaller life-stage, we used the date between the two runs of days to separate the smaller and larger size classes.

We saw a much higher fry outmigration in 1999 than in previous years, with more than an estimated 53% more migrants in 1999 than in 1998, the second largest estimate (Figure 8). Our numbers, however, may overestimate fry outmigration fluctuations between years since the traps were not installed at the same time. As discussed before, we began counting fry earlier in 1999 and fry passage continued until a later date in 1999 than in 1998 (1999 fry outmigration: January 18 - March 15; 1998 fry outmigration: Jan 29 - March 7). Since fry were already abundant on the first day of sampling in both 1996 and 1998, we are uncertain of the total abundance of fry outmigrants in either year. Many fry could have outmigrated during high flows in mid-January of both years before we began trapping.

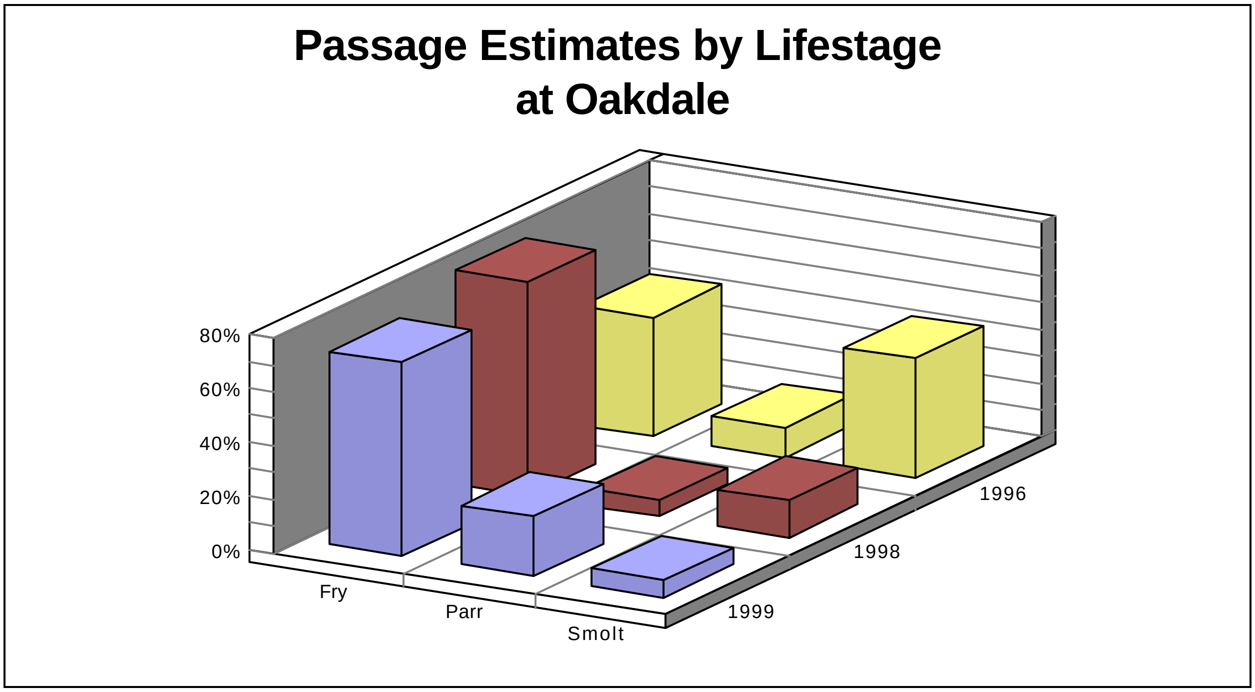


Figure 8. Fish abundance by life stage classification 1996-1999.

Parr abundance was fully sampled in 1996, 1998 and 1999. The abundance of parr migrants, 368,363, in 1999 was more than 10 times greater than in 1996. The differences between years are directly related to the number of days during which sampled chinook fell into the parr size class. The period when outmigrant parr fit the criterion (> 45 mm and < 80 mm) lasted only 10 days in 1996, 45 days in 1998 and 64 days in 1999. In 1999, the mean length was very near 80 mm for an extended period. Thus, an 80 mm demarcation between parr and smolt might be somewhat artificial, especially for the 1999 outmigration. In the future, combining the estimates of parr and smolt may be a more effective way to make comparisons among years.

The period of smolt outmigration was fully sampled in 1996, 1998 and 1999. Smolt abundance was lower in 1999 (102,493) than in 1998 (133,692) and 1996 (133,976), but not significantly different (Table 5). Confidence intervals overlap in all three years.

Table 5. Cumulative outmigration at Oakdale during the fry, parr, and smolt life-stages in 1996, 1998 and 1999.

1996 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Report)
Fry	02/02/96	03/16/96	134,769	26,024	83,762	185,777	02/02/96	03/20/96	119,796
Parr	03/17/96	04/06/96	33,531	4,091	25,513	41,548	03/21/96	03/31/96	11,453
Smolt	04/07/96	06/08/96	133,976	10,173	114,037	153,915	04/01/96	06/08/96	148,369
All	02/06/96	06/08/96	302,276	36,074	231,571	372,982	02/06/96	06/08/96	279,618

1998 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Report)
Fry	01/27/98	03/06/98	783,261	286,451	221,816	1,344,705	01/27/98	03/07/98	417,185
Parr	03/07/98	04/19/98	62,801	8,135	46,857	78,746	03/08/98	04/21/98	60,041
Smolt	04/20/98	07/15/98	133,692	14,857	104,573	162,811	04/22/98	07/15/98	121,824
All	01/27/98	07/15/98	979,754	285,613	419,953	1,539,555	01/27/98	07/15/98	599,050

1999 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits	
	Date Domain		Estimate	S.E.	Lower	Upper
Fry	01/18/99	03/22/99	1,198,144	213,879	778,941	1,617,347
Parr	03/23/99	05/26/99	368,363	64,353	242,231	494,496
Smolt	05/27/99	06/30/99	102,493	18,969	65,312	139,673
All	01/18/99	06/30/99	1,669,000	289,644	1,101,297	2,236,702

RATE OF JUVENILE CHINOOK MIGRATION

Average migration rates, estimated using the recaptured fish from the 1999 Oakdale efficiency releases, varied from 1.3 to 15.8 miles/night among the different release groups (maximum= 15.8 miles/night, minimum=1.3 miles/night). Of the seven fish recaptured from

Oakdale survival and efficiency releases, two fish (29%) took more than two weeks to travel from Oakdale to Caswell (Table 6). This supports the hypothesis that rearing may take place between Oakdale and Caswell in some years.

Table 6. Recaptures from Oakdale efficiency groups at Caswell State Park.

Night	O1	O2	O3	O4	O9
1					
2	1				
3					
4					
5				1	
6					
7					
8		3			
9					
10					
11					
12					
13					
14					1
15					
16					
17					
18					
19					
20					
21					
22					
23					
24			1		
Total Fish	1	3	1	1	1
avg. days	2.0	8.0	24.0	5.0	14.0
miles/day	15.8	3.9	1.3	6.3	2.3
flow	4,129	4,158	3,535	2,641	1,146
mean rec. LN	34.2	35.8	35.2	35.8	49.6

Outmigration past Oakdale and Caswell

The number of chinook outmigrating past Oakdale and Caswell sites were compared to estimate fish survival between RM 40.1 and RM 8.6. Overall, in 1999 more fish passed the

Oakdale (1,669,000 chinook) trap than the Caswell (1,321,042 chinook) trap. This suggests that 21% of the fish (347,958 chinook lost out of 1,669,000) were subject to mortality or extraction between the two sites. Only a small proportion of the difference occurred between the categories of fry and smolts (12%- 42,720 fry and 8%-29,490 smolts), while 79% of the difference was in the parr category (275,748 parr) (Figure 9). Most parr that passed Oakdale may have grown to the smolt size category before reaching Caswell, but survival of such rearing fish may have been low, because both the number of parr and smolts estimated to pass Caswell were less than those passing Oakdale.

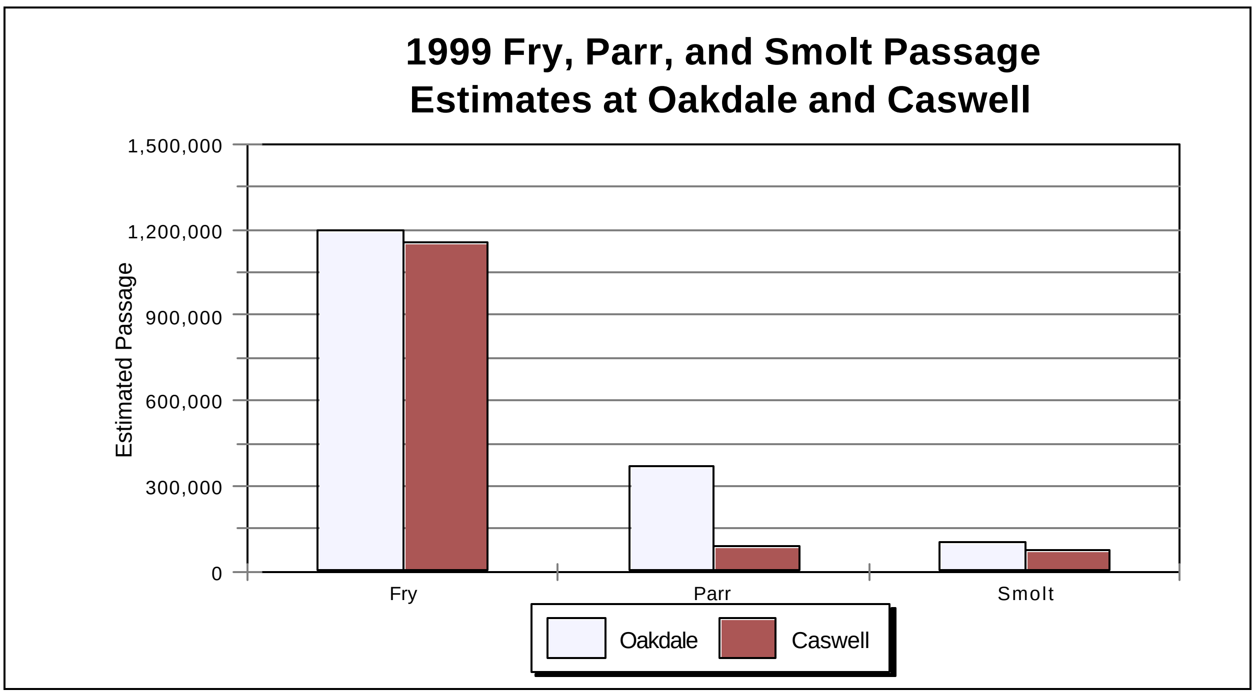


Figure 9. Abundance of fry, parr and smolts at Caswell and Oakdale, 1999.

OBJECTIVE 2: DETERMINE THE SIZE AND SMOLTING CHARACTERISTICS OF JUVENILE CHINOOK SALMON AND RAINBOW TROUT/STEELHEAD MIGRATING OUT OF THE STANISLAUS RIVER.

LENGTH AT OUTMIGRATION

The mean lengths of juvenile chinook gradually increased over the course of sampling, ranging from about 35 mm at the start of sampling (mid-January) to about 90 mm in late June (Figure 10). The gradual increase in mean lengths over time seen in 1999 resembled the pattern seen in 1996, 1997, and 1998; though the pattern was more sigmoidal in 1996 (Figure 11). In 1996, fish lengths were static during the fry outmigration, but increased quickly during the parr stage. In that year, they grew more slowly during the smolt stage (much like the fry stage), giving the sigmoidal pattern. The rapid increase in length from fry to smolt was not observed in the 1998 or 1999 data, suggesting that same factor was stimulating parr to migrate in these years.

Environmental factors—such as water temperature and turbidity—may play roles in determining the lengths at which juvenile chinook are stimulated to migrate. These factors are discussed in this section. Several other factors may also affect the length of migrants, but were not examined in this study. For example, late fall spawners may produce the smaller fish seen later in the season. While spawner data has not yet been incorporated into the study, this information could help us determine how biological and physical variables affect growth and length of chinook at outmigration. In addition, density dependence, with territorial behavior and habitat availability, may explain the difference in parr and smolt lengths in some years. Since chinook are highly territorial and their territory expands as they grow, many fish could be displaced downstream in search of unoccupied habitat during years when juvenile densities are high.

Mean Lengths of Natural Migrants Between Years

Mean lengths of fry captured during January and February each year were very similar (35-37mm), but the lengths of parr during March varied some years. Since 1996, the mean length of parr in March has been less each year (Figure 12). Therefore, as part of this study, we examined two factors, water temperature and turbidity, that could affect growth between years. Fish abundance is also an important factor that could affect growth and deserves more consideration. To explore this potential relationship, however, we need better information about fish abundance in the Stanislaus.

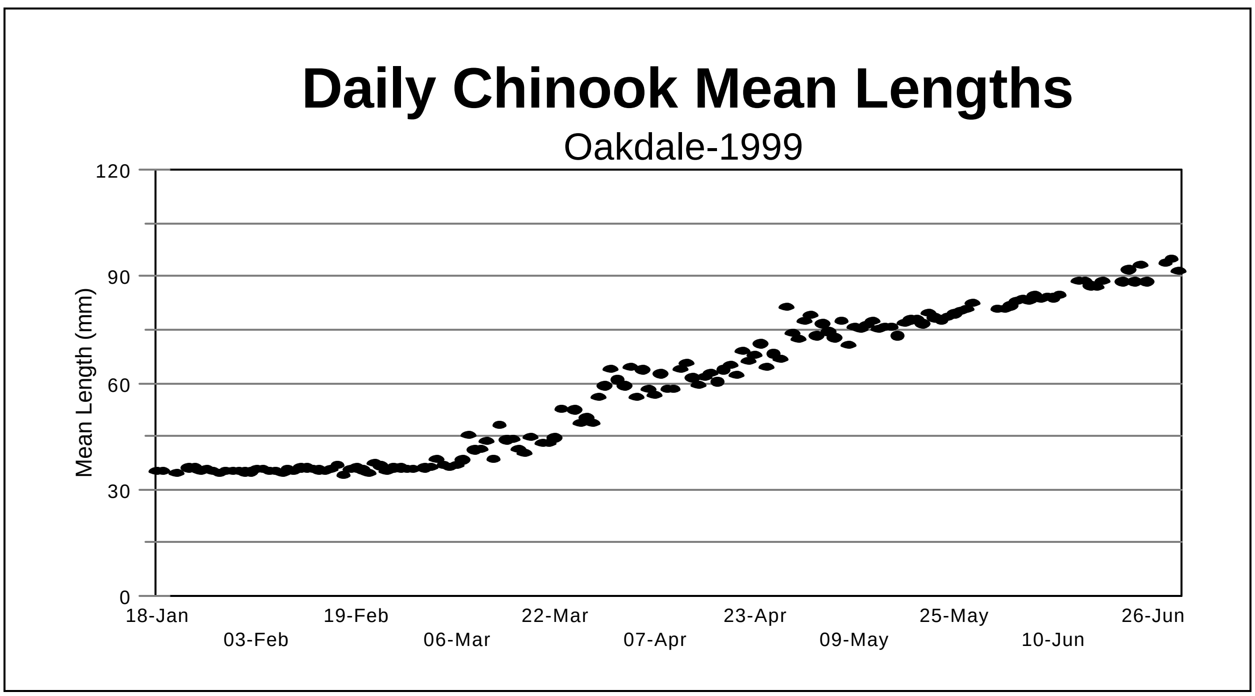
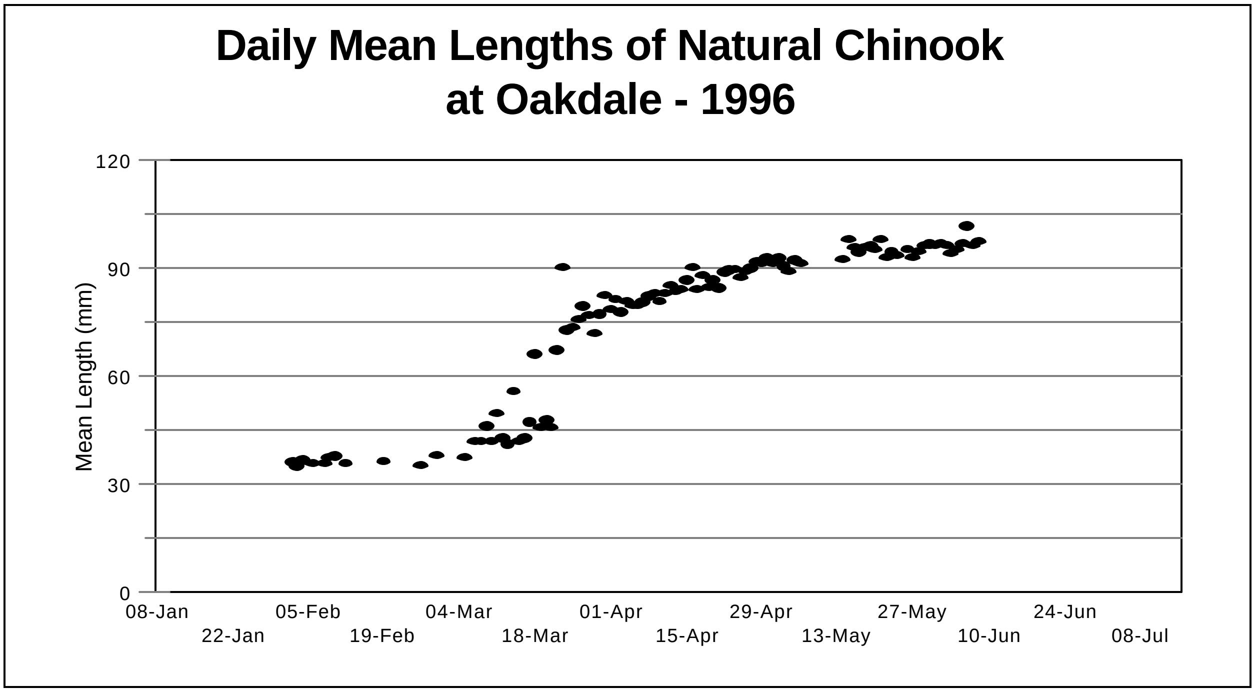


Figure 10. Mean lengths of chinook captured at Oakdale in 1999.



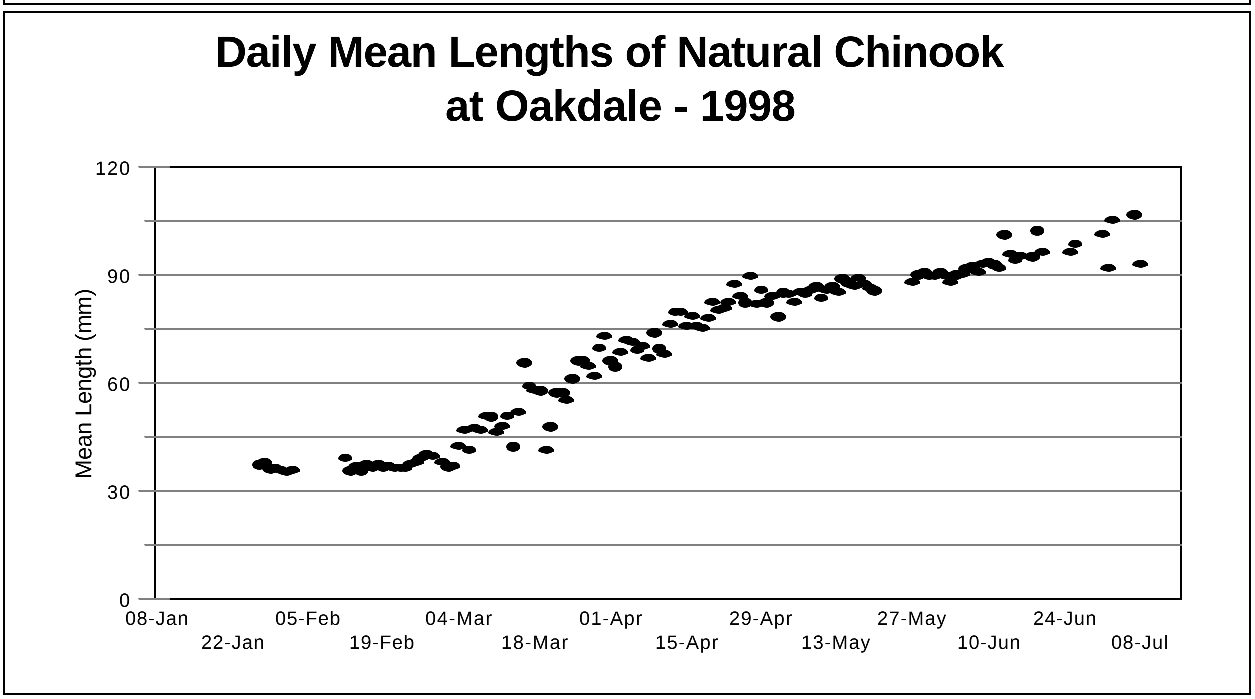


Figure 11. Mean lengths of chinook captured at Oakdale 1996-1998.

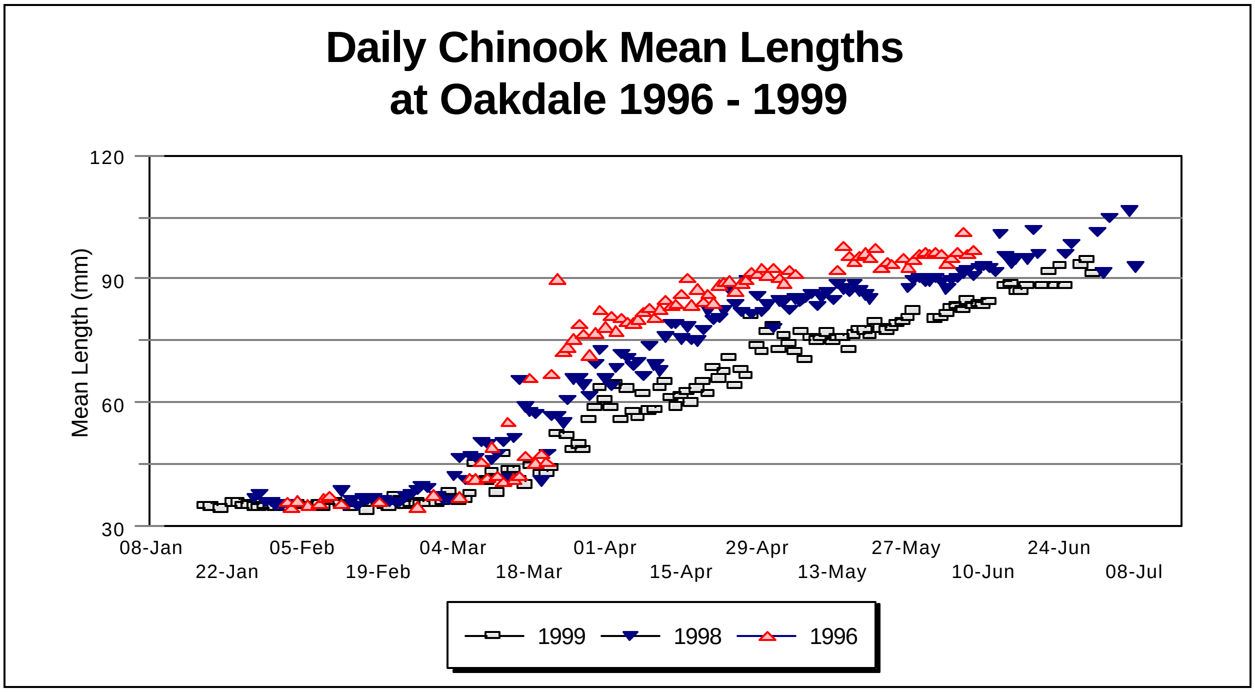


Figure 12. Mean lengths of chinook captured at Oakdale, 1996-1999.

Influence of Temperature on Length at Outmigration

Rearing temperature data at Goodwin Dam for 1998 and 1999 show that temperatures in the reach were slightly cooler during January, February, and March of 1999 (Figure 13). These cooler temperatures could have contributed to slower growth and smaller mean lengths of parr and smolts in these years. Laboratory experiments have definitively established that water temperature has a strong influnce on growth of juvenile salmon, with temperature of ___, producing optimum growth when food supply is not limiting (Brett ??). Thus, temperatures of 49 to 51EF during January through March are well below the optimum for growth of juvenile chinook. However, temperatures in 1996 were very close to those in 1998, and fish were larger in 1996 than 1998 (___mm on April 1, 1996 versus ___mm on April 1, 1999). This difference suggests that temperature is not the only factor influencing fish growth.

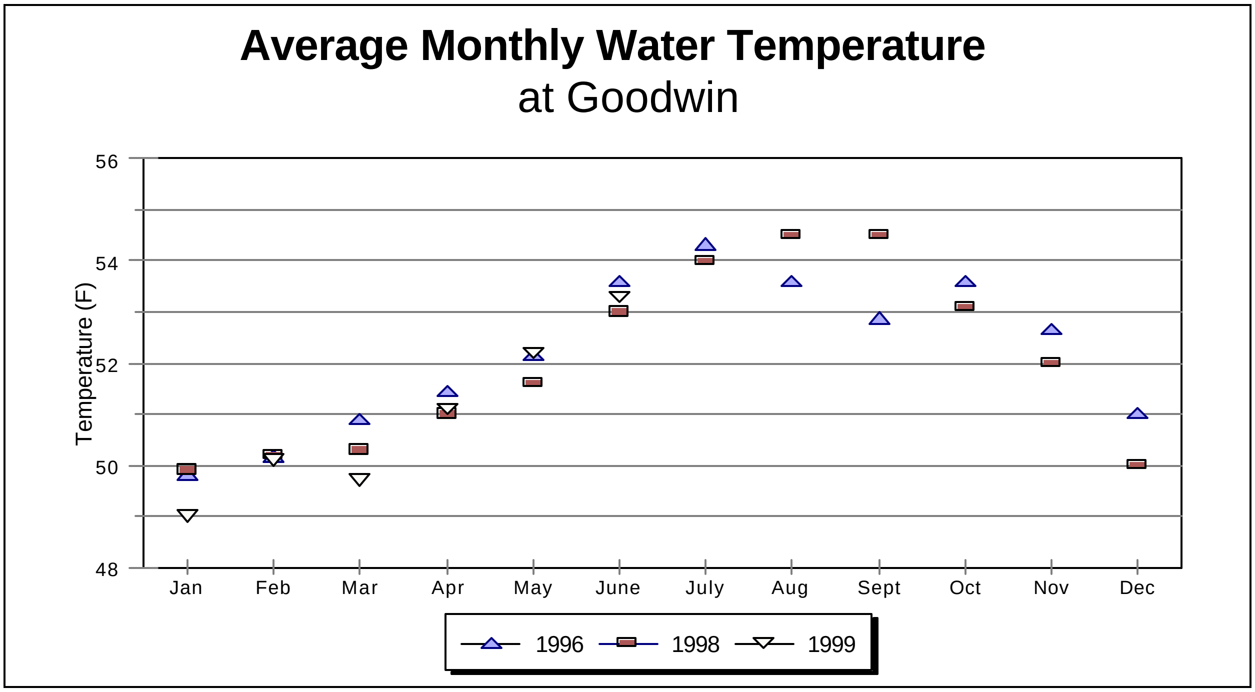


Figure 13. Average monthly temperatures at Goodwin Dam 1996 through 1999.

Incubation temperature during fall and early winter, which may play a key role in chinook development and emergence, may also partially explain differences in length. Fish outmigrating in 1999 experienced cooler incubation temperatures during November and December than those in 1997 (Figure 14). Thus, emergence timing would have been slightly later in 1999 and this would have given fish a head start on growth in 1996.

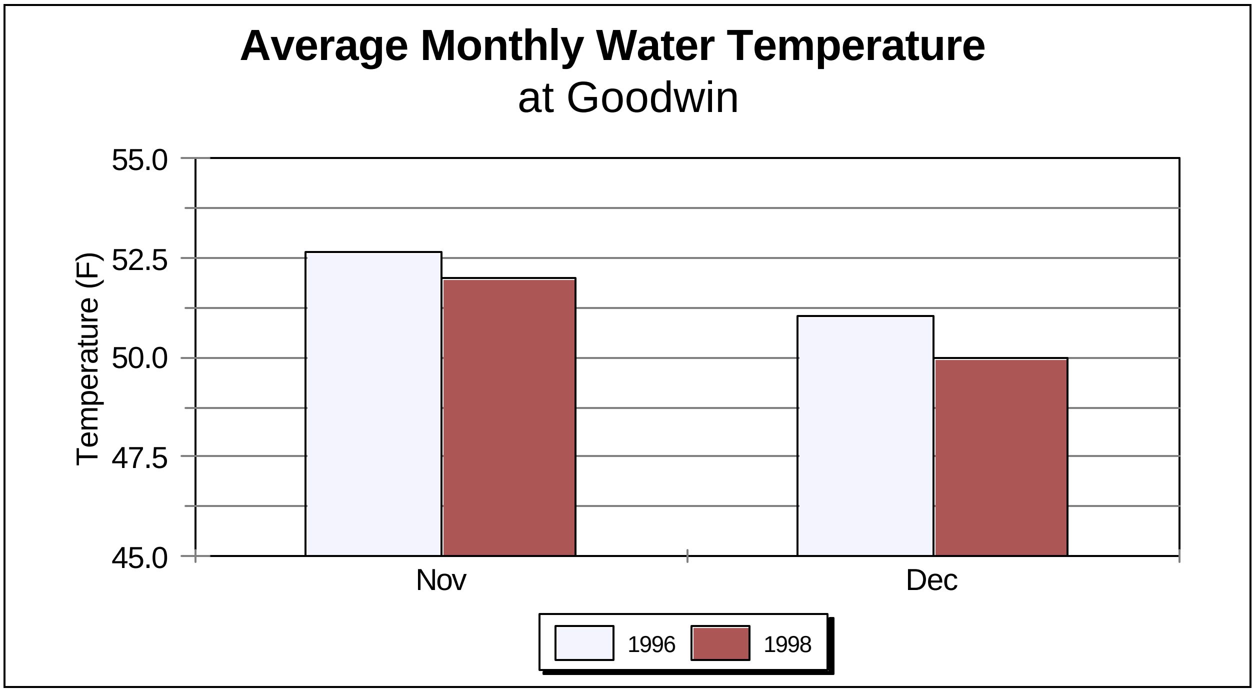


Figure 14. Fall spawning and incubation temperatures for 1996 (1997 fry) and 1998 (1999 fry) at Goodwin Dam.

Influence of Turbidity on Length at Outmigration

During turbid conditions, studies suggest that juvenile fish may engage in activities, such as increased feeding, that would otherwise be risky (Ginetz and Larkin 1976). If turbidity promotes greater foraging activity and extends the suitable habitat range by providing cover, then we would expect larger fish to be produced in years of high turbidity. Our review of turbidity levels in 1996, 1998 and 1999 revealed that turbidity levels were lowest in 1999 and highest in 1998. Differences in turbidity between years (Figure 15) did not correlated with differences in chinook lengths.

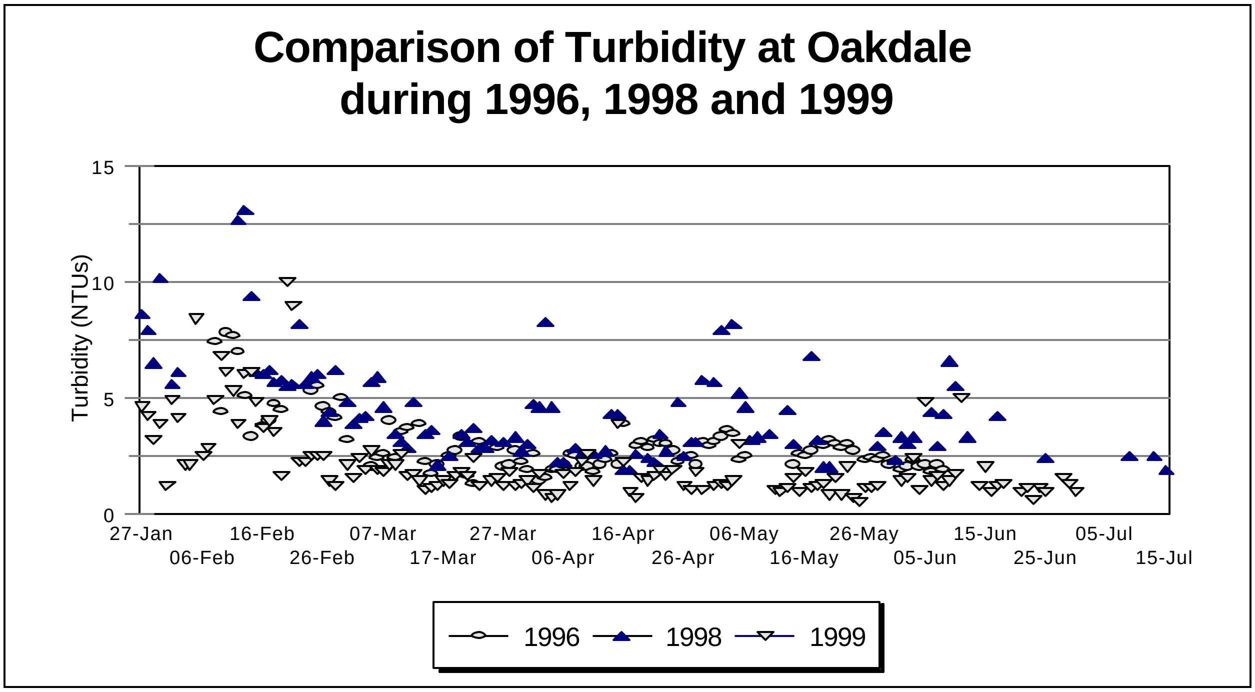


Figure 15. Turbidity levels for 1996, 1998, and 1999.

Comparison of Mean Lengths at Oakdale and Caswell in 1999

Mean lengths of natural chinook captured throughout the trapping season at Caswell and Oakdale have been similar in past years. In 1999, however, there was a noticeable difference in mean lengths between the sites beginning in March when fish reached the parr stage (Figure 16). This difference was most dramatic in mid-April, when fish reached approximately 60 mm in length at Oakdale, but were already 75 mm at Caswell. In past years, when daily mean lengths were nearly identical at both Oakdale and Caswell, we assumed that chinook were migrating quickly through the Stanislaus without stopping to rear on the way (Figure 17). The difference in mean lengths seen between the two sites in 1999 suggests that fish may rear between the two sites.

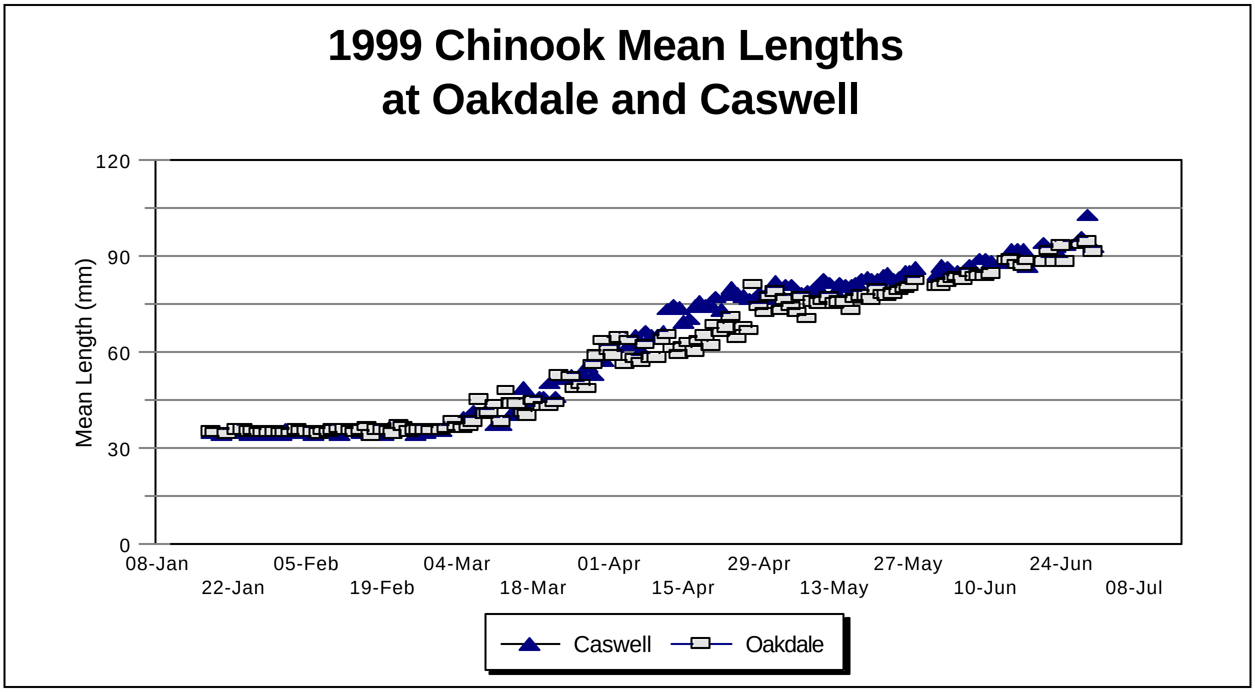
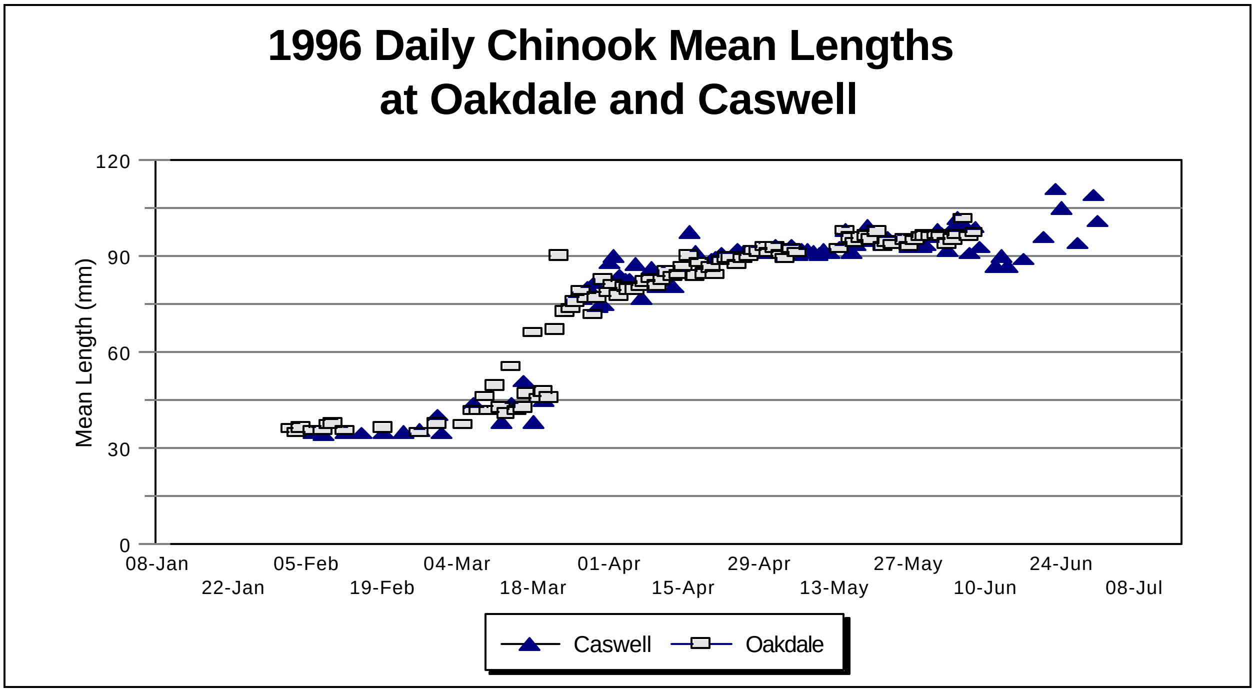


Figure 16. Comparison of mean lengths at Oakdale and Caswell in 1999.



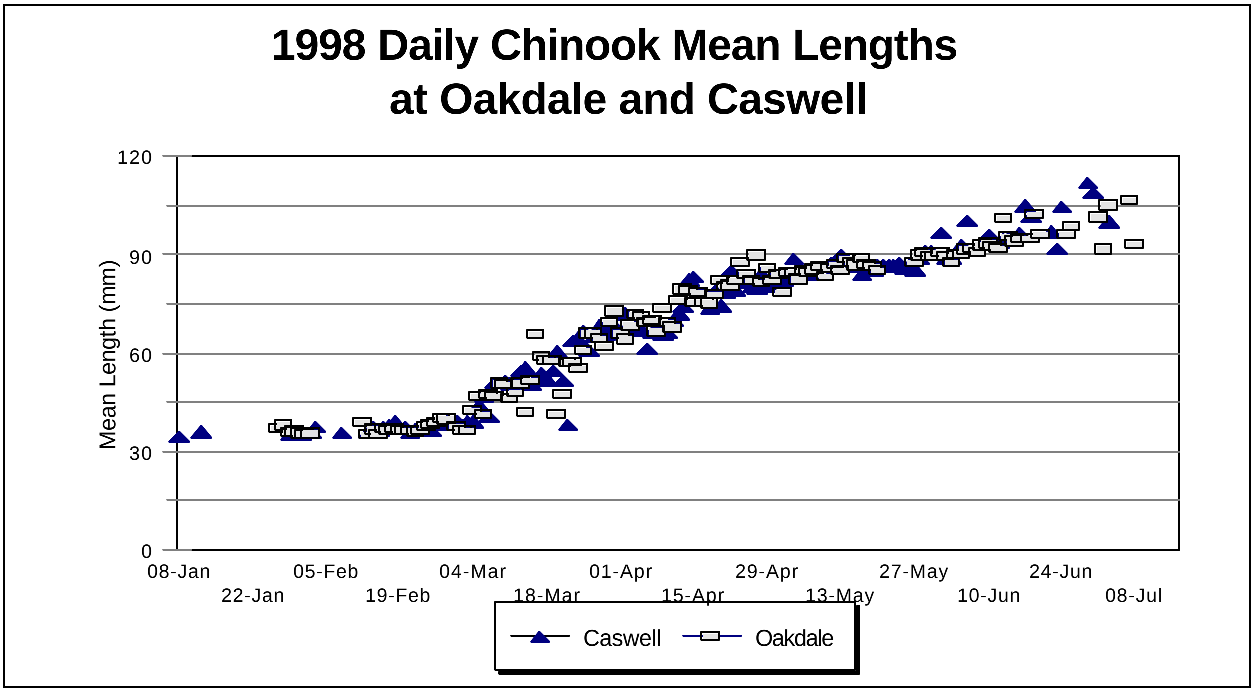


Figure 17. Comparison of mean lengths at Oakdale and Caswell in 1996 and 1998.

SMOLT APPEARANCE

Chinook captured in the traps began showing more visible smolt characteristics in March (Figure 18), when the daily mean smolt index gradually increased from 1 to 2. Individual fish with a score of 2 appeared through mid-June and ranged up to 90 mm. Fish that were distinctly smolts (index = 3) were 80 mm and above, and began appearing in June.

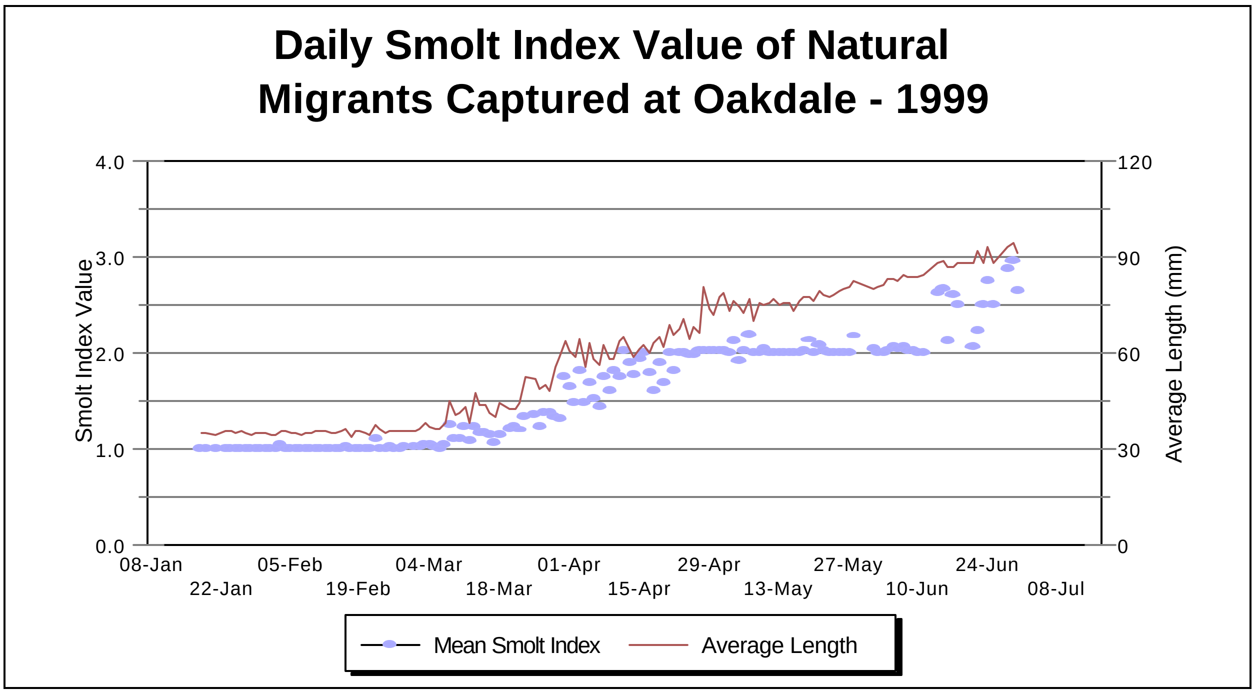


Figure 18. Mean daily smolt index value of natural chinook captured in the Caswell screw traps during 1999 and lengths of juvenile chinook.

Smolt indexes for the 1998 and 1999 outmigrations showed little variation. Fry (smolt index 1) were present through the end of April in both 1998 and 1999, except for one fry captured in late May 1999. Parr (smolt index 2) appeared later in 1999 (beginning of March) than in 1998 (late February), but in both years parr outmigrations persisted until mid-June. In both years smolts (smolt index 3) were observed from about April 15 through the sampling period until the end of June. The difference in the timing of parr could be attributed to a variety of factors affecting growth and development, which were previously mentioned in relationship to length.

RAINBOW TROUT/STEELHEAD

During the sampling season, we captured 44 rainbow trout/steelhead at Oakdale, ranging in size from 31 mm to 365 mm (Figure 19). The first rainbow/steelhead was captured soon after sampling began on January 18 and the last was captured on June 25. Rainbow/steelhead (> 200 mm long) were caught January through May, and young-of-year rainbow (<100mm) were caught April through June. Two distinct size classes emerged from the data (200-300 mm and <100mm), most likely representing yearlings and young-of-year, respectively. More rainbow/steelhead were captured in 1999 than in 1998, nearly double the highest previous count of 23 rainbow/steelhead in 1995.

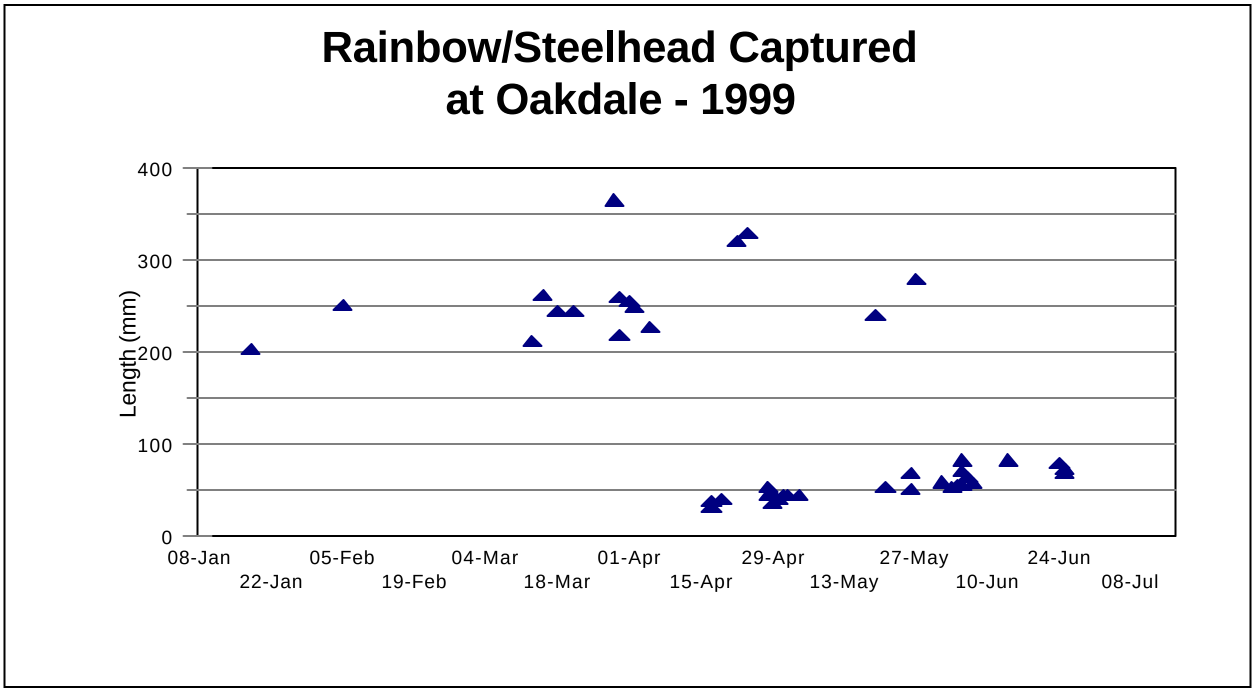


Figure 19. Lengths of all rainbow trout/steelhead captured at Oakdale 1999.

OBJECTIVE 3: IDENTIFY FACTORS THAT INFLUENCE THE TIMING OF JUVENILE CHINOOK SALMON MIGRATING OUT OF THE STANISLAUS RIVER.

INFLUENCE OF FLOW ON CHINOOK OUTMIGRATION

Related studies suggest that, in some instances, peak flows may cue fish to migrate. For example, in the Sacramento-San Joaquin delta, Kjelson et al. (1981) found that peak catches were often associated with flow increases caused by storm runoff. They speculated that flow pulses stimulated fry migration from upper river spawning grounds. In 1999, we did not find a strong relationship between increased flows and chinook migration in the Stanislaus River. During the sampling period, chinook fry passage peaked in January as flows increased but fry passage peaked again in early February as flows decreased and then a second time as flows increased (Figure 20). Fry passage estimates were high throughout January and February, with daily passage estimates exceeding 20,000 fry on 15 days at the Oakdale trapping site.

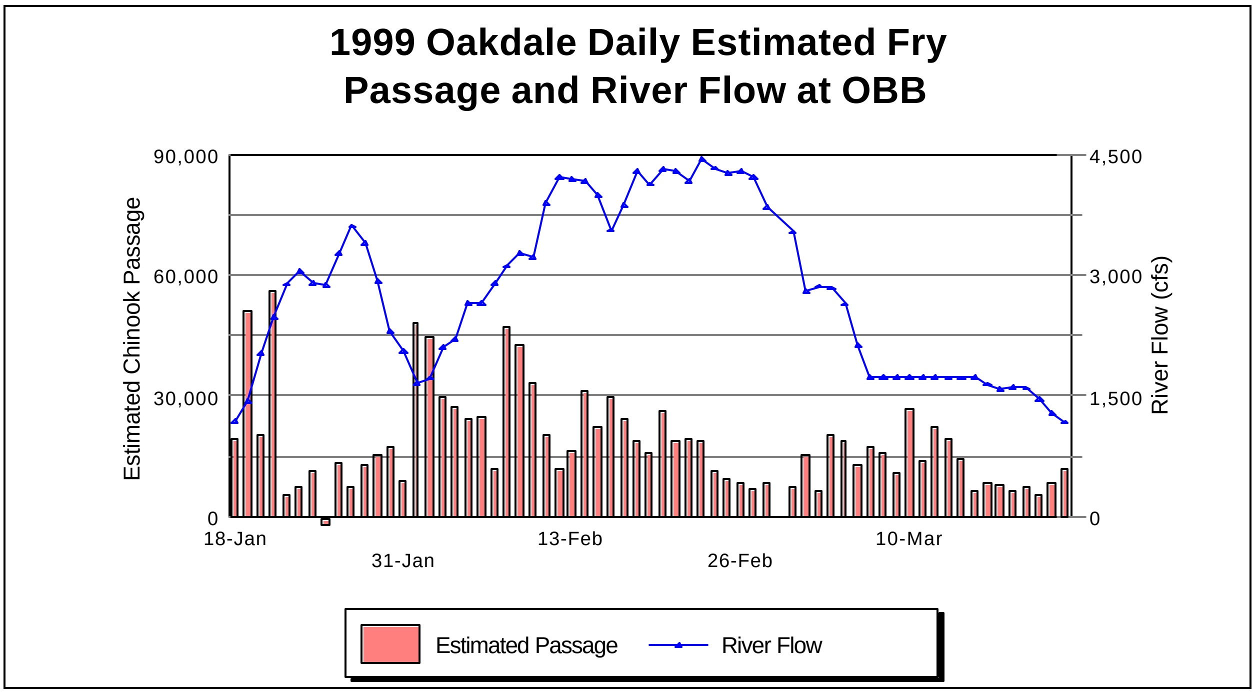


Figure 20. Fry outmigration index and flow for 1999.

Migration down the Stanislaus River peaked in mid-February during 1996 and 1998 (fry outmigration was not sampled in 1997), and in January of 1999. However, during 1996 and 1998, we began sampling late and may have missed peaks before those seen in mid-February. Also, we were unable to sample during the highest flows of 1998, which occurred in early February. In 1996 and 1998, passage peaks were associated with an increase in daily average flow of 300 to 700 cfs. During, 1999, fry outmigration peaked in January and did not coincide with peak flows or an increase in flows. This suggests that flows influence fry migration, but are not the sole mechanism.

During the 1999 parr and smolt outmigration between March and June, flows remained stable for extended periods and changed 300 to 500 cfs in one day on several occasions (Figure 21). These changes constituted no more than 35% of the base flow on that date. Daily numbers of juvenile outmigrants fluctuated widely during March through June and did not show a strong correlation to changes in flow. Small peaks in outmigration did occur in times of lowered and increased flows, but they lasted only a day and were usually followed by a sharp decline. Similar results were observed on the upper South Umpqua River basin, Oregon, where 50-59 mm chinook (parr) were not cued to migrate by changes in discharge (Roper and Scarnecchia 1999).

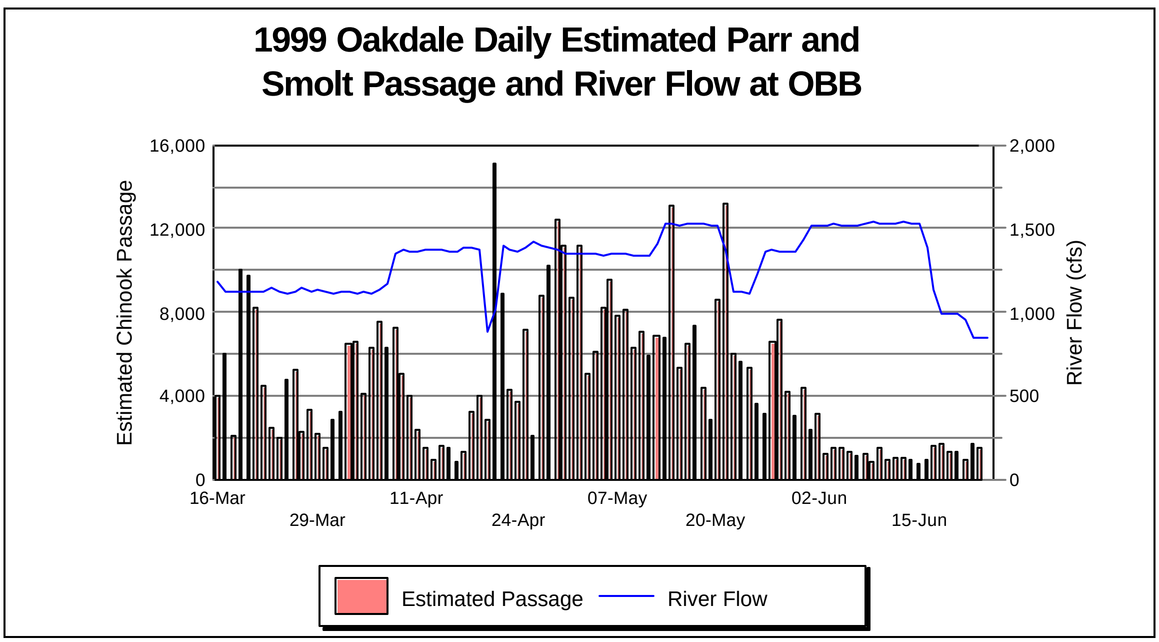


Figure 21. Parr and smolt outmigration index and flow for 1999.

In past years, we have found that chinook smolts were stimulated to migrate by a distinct change in flow, but the effect lasted only a few days and only a portion of the fish were affected. The protracted period over which parr grew into the smolt stage (>80mm) in 1999, probably reduced the proportion of fish that were physiological ready to migrate on any give date that flow changed.

INFLUENCE OF TURBIDITY ON CHINOOK OUTMIGRATION

Fry outmigration peaked during January and February of 1999 when turbidity levels were high, ranging from about 0.7 to 25 NTU's (Figure 22). Except for one large increase of turbidity in January, daily turbidity levels for the period usually ranged from 1 to 6 NTU's.

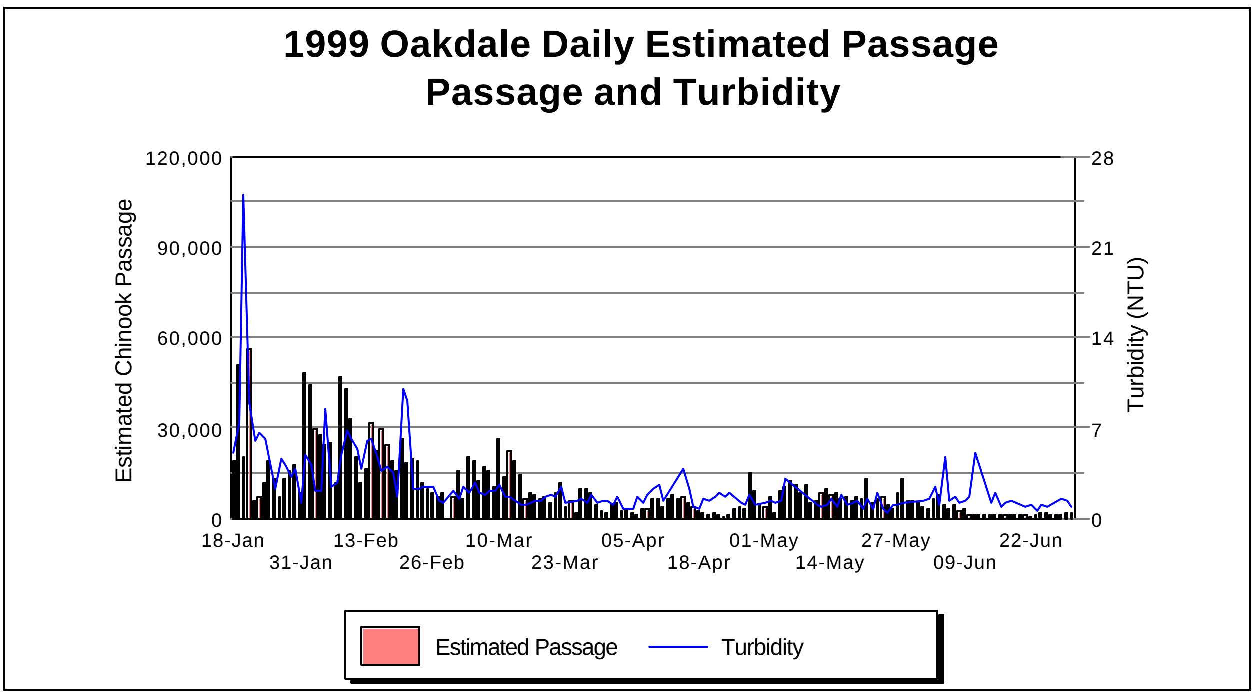


Figure 22. Oakdale daily passage and turbidity.

We recorded the highest fry passage on January 21, the day after the first recorded turbidity spike (25 NTU's on January 20). We do not know how many fish passed the site on January 20 as the trap was not operating and no catch was recorded. After February, and during the parr and smolt outmigration, turbidity ranged from approximately 2 to 7 NTU's. This corresponded with some peaks in passage, but not consistently.

While little research exists on the relationship between turbidity and fry outmigration timing, many studies have related turbid conditions to reduced fry predation. Predators, such as birds and fish, use vision to detect and attack prey. High turbidity can impair visual abilities, thus reducing the detection range of predators and allowing small fish to outmigrate undetected. Studies suggest that juvenile fish take up more dangerous activities during turbid conditions, such as feeding (Gregory and Northcote 1993, Gregory 1994), using open water areas (Miner and Stein 1996), migrating (Ginetz and Larkin 1976), and seeking less cover (Gradall and Swenson 1982, Gregory 1993). Thus, fry may prefer to migrate during turbid conditions, and changes in turbidity could act as a cue.

INFLUENCE OF FISH LENGTH ON CHINOOK OUTMIGRATION

Variations in peak fry emergence among the years were probably not related to fish size, as fry were of a consistent range (35-45 mm) in 1996, 1998, and 1999. Fry were 35-37 mm at the onset of sampling and at outmigration. This size is within the ranges found for other populations (Mains and Smith 1964, Lister et al. 1971, Healey et al.1977 cited from Healey 1991).

Because there was no distinct peak in outmigration of parr and smolts during 1999, there was no clear relationship between their lengths and migration timing (Figure 23). Overall, there were greater numbers of migrants during May than during April, and there was a high proportion of juveniles that qualified as smolts (>80mm) in May but a small proportion in April. Thus, the greater number of smolt migrants is consistent with past findings that fish have a greater propensity to migrate when they are larger than 80 mm than when they are 45-80mm (parr). No yearlings were captured during the 1999 trapping season.

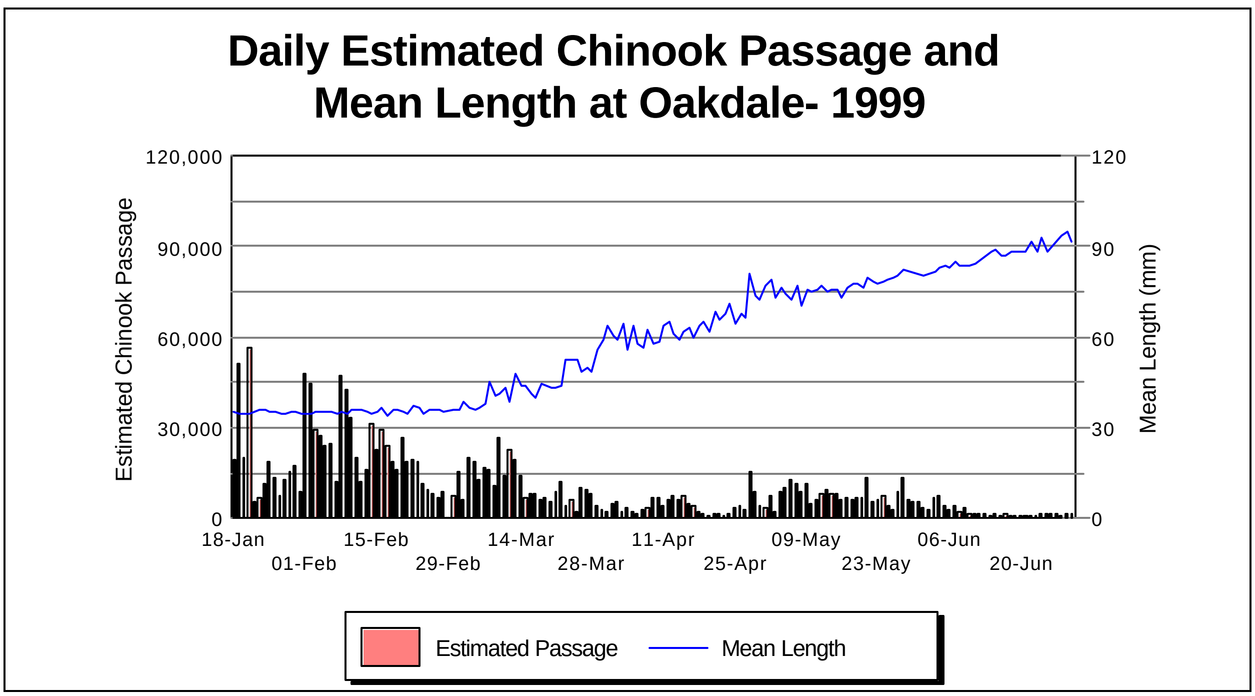


Figure 23. Mean length and chinook passage estimate for 1999.

INFLUENCE OF TEMPERATURE ON CHINOOK OUTMIGRATION

Stream temperature at Oakdale gradually increased from near 46° F at the start of sampling to 57° F at the end of June (Figure 24). Fluctuations in outmigration did not appear to correspond with changes in temperature during this time. It is possible that temperature influences outmigration is some ways, but the effects of temperature alone are difficult to measure.

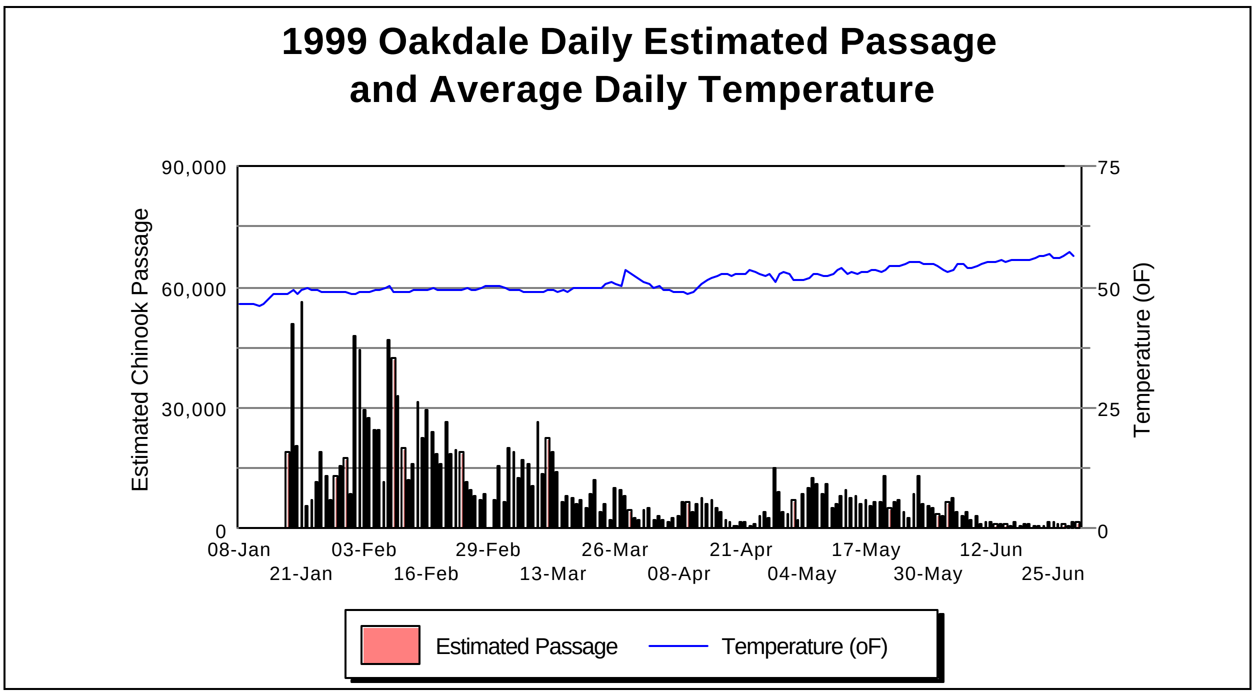


Figure 24. Oakdale daily estimated passage and average daily water temperature.

Influence of Incubation Temperature on Fry Migration Timing

Water temperatures can be used to predict the start of fry emergence. Temperatures at Goodwin Dam were recorded and used to do a simple degree day analysis to estimate when fry first emerged. A degree day is 1 EF above freezing for one day. The sum of degrees above freezing for a given period of days would show how many degree days were experienced for that period. Incubation temperatures were available during the fall of 1998, corresponding to the outmigration of 1999. In 1998, chinook spawners arrived at spawning gravels in Knights Ferry around October 15 (personal communication, Duane Johnson, Army Corp. of Engineers). Given this date, we summed average daily temperature until we achieved 888 degree days (literature value for emergence, Piper et al. 1998) and estimated that emergence began on January 5. This is consistent with trapping data. Traps were not fished until January 18, when passage estimates already exceeded 10,000 fish/day. Thus, the start date of January 5 is not an unlikely estimate, though it does suggest that traps should be installed earlier if the entire run is to be sampled.

CONCLUSIONS

! An estimated 1,669,000 juvenile chinook migrated down the Stanislaus River past Oakdale from January 18 through June 30, 1999, with a 95% confidence interval of 1,101,297 to 1,668,994 migrants. Outmigrant abundance was greatest on January 21 when an estimated 56,176 chinook fry migrated past the trap. Though our analysis shows a much higher fry outmigration in 1999 than in previous years, actual run sizes were probably much closer. Traps were installed later in 1996 and 1998 after many fry had already migrated past the site. Also, many fry passed the trap site during high flows in February 1998 when the trap was not functioning.

! By far, most of the juvenile chinook migrants passed the trap site at Oakdale as fry (<45 mm). Fewer of the juvenile chinook outmigrated through the area as parr (45-80 mm) and smolt (>80 mm). Our passage estimates show that the fry outmigration in the Stanislaus River is even higher than the almost 1.2 million fry emigrants estimated for 1999. When we began fishing the traps on January 18, 1999, chinook passage estimates already exceeded 10,000 fish/day. While our sampling period started earlier in 1999 than in previously years, we probably need to install the traps by the start of January to sample the entire run.

! In past years, fish captured at Caswell and Oakdale have been similar in mean length so we assumed they were migrating quickly through the Stanislaus without stopping to rear. This pattern changed during the 1999 sampling. In 1999, there was a noticeable difference in mean length between sites beginning in March when the fish reached the parr stage. The difference is most dramatic in mid-April, when fish at Oakdale reached approximately 60 mm in length, but fish at Caswell were 75mm in length. This suggests that fish may rear between Oakdale and Caswell in some years.

- To sample parr abundance, we considered chinook to be parr when they ranged in size from >45 mm and <80 mm. However, in 1999 the mean length was very near 80 mm for an extended period. Because of this, the 80 mm demarcation between parr and smolts may be somewhat artificial. We may want to combine the estimates for parr and smolt in the future when making comparisons among years.

- The 1999 peak fry outmigration in January coincided with increases in flow and the February passage peaked twice, once during increasing flow and once during decreasing flows. The number of migrants dropped quickly in mid-March when flows declined from over 4,000 cfs to less than 2,000 cfs. From March through June 1999, when most parr and smolt outmigration occurred, outmigrant numbers fluctuated weekly and did not show a clear pattern related to flow.

- Fry outmigration peaks during January and February 1999 occurred when turbidity levels were high, ranging from 0.7 to 25 NTU's. The highest number of fry passed Oakdale on January 21, the day after the first recorded jump in turbidity (25 NTU's on January 20). We do not know if a large number of fry also outmigrated past the site on January 20 since our trap was not functioning. During the parr and smolt outmigration, turbidity corresponded with some peaks in passage, but not consistently. These results suggest that fry may prefer to migrate during turbid conditions, and changes in turbidity may act as a cue.

- In 1999, water temperature at Oakdale gradually increased from near 46º F at the start of sampling to 57º F at the end of June. Fluctuations in chinook outmigration did not appear to correspond with changes in temperature.

! Two of the seven recaptured fish used in the Oakdale efficiency releases took more than two weeks to travel from Oakdale to Caswell. This— combined with the noticeable difference in mean fish lengths for the sites beginning in March when fish reached the parr stage—supports the theory that fish may occasionally rear between the sites.

! Migration rates were comparable to previous years. Average migration rates in 1999, estimated using the recaptured fish from the Oakdale efficiency releases, varied from 1.3 to 15.8 miles/night.

RECOMMENDATIONS

Based on our findings during the 1999 study, we recommend that the study be revised in the following ways. These improvements are needed to fully examine juvenile chinook salmon migration in the Stanislaus River and factors that influence their growth and migration timing.

1. Begin sampling the juvenile chinook outmigration in mid-December. We found in 1999 that juvenile chinook were already migrating when we began sampling in early January. Thus, our migration estimates only capture a portion of the run. We can better estimate the size and timing of the outmigration by beginning our sample period before the run begins. This will also allow us to more accurately compare outmigration estimates between years.

2. Obtain spawner and abundance data from the California Department of Fish and Game. This data is needed to conduct a degree day analysis and examine the potential relationship between fry emergence and fry outmigration timing.

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LITERATURE CITED

Barret, J.C., G.D. Grossman, and J. Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. Transactions of the American Fisheries Society 121:437-443.

Beacham, T.D. and C.B. Murray. 1990. Temperature, egg size, and development of embryos and alevins of five species of Pacific salmon: A comparative analysis. Transactions of the American Fisheries Society 119:927-945.

Bjornn, T.C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Transactions of the American Fisheries Society 100 (3):423-438.

Bjornn, C. D.R. Craddock, and D.R. Croley. 1968. Migration and survival of Redfish Lake, Idaho sockeye salmon (*Oncorhynchus nerka*). Transactions of the American Fisheries Society 97(4):360-373.

Cezilly, F. 1992. Turbidity as an ecological solution to reduce the impact of fish-eating colonial waterbirds on fish farms. Colonial Waterbirds 15(2):249-252.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. The American Naturalist 100:345-357.

Chapman, D.W., and T.C. Bjornn. 1969. Distribution of salmonids in streams with special reference to food and feeding. Pages 153-176 *in* T.G. Northcote (ed.). Symposium on salmon and trout streams. H.R. MacMillan lectures in Fisheries. Institute of Fisheries, University of British Columbia, Vancouver, BC 388p.

Cramer, S.P. and D.B. Demko. 1993. Effects of pulse flows on juvenile chinook migration in the Stanislaus River. Final Report, S.P. Cramer & Associates, submitted to TriDam Project, Pinecrest, California. 39 p + appendices.

Demko, D.B. and S.P. Cramer. 1995. Effects of pulse flows on juvenile chinook migration in the Stanislaus River. Annual Report for 1995. Prepared by S.P. Cramer & Associates, Inc. for Oakdale Irrigation District, Oakdale, CA, and South San Joaquin Irrigation District, Manteca, CA.

Demko, D.B. and S.P. Cramer. 1997. Outmigration trapping of juvenile salmonids in the lower Stanislaus River, Caswell State Park site 1996. Prepared by S.P. Cramer &

Associates, Inc. for U.S. Fish and Wildlife Service, Stockton, CA.

Demko, D.B. and S.P. Cramer. 1998. Outmigration trapping of juvenile salmonids in the lower Stanislaus River, Caswell State Park site 1997. Prepared by S.P. Cramer & Associates, Inc. for U.S. Fish and Wildlife Service, Stockton, CA.

.

Demko, D.B., C.K. Gemperle, A. Phillips and S.P. Cramer. 1999. Evaluation of juvenile chinook behavior, migration rate and location of mortality in the Stanislaus River through the use of radio tracking-1998. Final report to Tri-dam.

Demko, D.B., C.K. Gemperle, A. Phillips and S.P. Cramer. 1999. Outmigrant trapping of juvenile salmonids in the lower Stanislaus River Caswell State Park site-1998. Final report to U.S. Fish and Wildlife Service.

Elliot, J.M. 1990. Mechanisms responsible for population regulation in young migratory trout, *Salmo Trutta*. III. The role of territorial behavior. Journal of Animal Ecology 59:503-818.

Everest, F.H. and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of Fisheries Reserve Board Canada 29:91-100.

Ginetz, R.M. and P.A. Larkin. 1976. Factors affecting rainbow trout (*Salmo gairdneri*) predation on migrant fry of sockeye salmon (*Oncorhynchus nerka*). Journal of Fisheries Reserve Board Canada 33:19-24.

Gradwell, K.S. and W.A. Swenson. 1982. Responses of brook trout and creek chubs to turbidity. Transactions of the American Fisheries Society 11:392-395.

Grau, E.G., W.W. Dickhoff, R.S. Nishioka, H.A. Bern, and L.C. Folmar. 1981.Lunar phasing of the thyroxine surge preparatory to seaward migration of salmonid fish. Science 211:607-609.

Gregory, R.S. 1993. Effect of turbidity on the predator avoidance behavior of juvenile chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 50:241-246.

Gregory, R.S. 1994. The influence of ontogeny, perceived risk of predation and visual ability on the foraging behavior of juvenile chinook salmon. Pp.271-284. *In*: D.J. Stouder, K.L. Freah and R.J. Feller (ed.) Theory and Application in Fish Feeding Ecology. Belle Baruch Lib. Mar. Sci. No. 18, University of South Carolina Press, Clochemerle.

Gregory, R.S. and C.D. Levings. 1996. The effects of turbidity and vegetation on the risk of juvenile salmonids, *Oncorhynchus* spp., to predation by adult cutthroat trout, *O. Clarkii*. Environmental Biology of Fishes 47:279-288.

Gregory, R.S. and C.D. Levings. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Fisheries Society 127:275-285.

Gregory, R.S. and C.D. Northcote. 1993. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Fisheries Society 127:275-285.

Hart, P.J.B. and T.J. Pitcher. 1969. Field trials of fish marking using jet inoculator. J. Fish Biol. 1;383-385.

Healey, M.C., R.V. Schmidt, F.P. Jordan, and R.M. Hungar. 1977. Juvenile salmon in the Nanaimo area 1975. 2: length, weight, and growth. Fish. Mar. Serv. (Can) ms Rep. 1438:147p.

Healey, M.C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia, p.203-229. *In*: W.J. McNeil and D.C. Himsworth (eds.). Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis, OR.

Healey, M.C. 1991. Life history of chinook salmon. Pages 313-393 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver.

Heming, T.A. 1982. Effects of temperature on utilization of yolk by chinook salmon (*Oncorhynchus tshawytscha*) eggs and alevins. Canadian Journal of Fisheries and Aquatic Sciences 39:184-190.

Karas, N. 1974. The Striped Bass. Lyons & Burford Publishers, New York.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1981. Influences of freshwater inflow on chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin estuary, p. 88-102. *In*: R.D. Cross and D.L. Williams (eds.). Proceedings of the National Symposium on Freshwater Inflow to Estuaries. U.S. Fish Wildl. Serv. Biol. Serv. Prog. FWS/OBS-81/04(2).

Lister, D.B., and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (*Oncorhynchus tshawytscha*) and coho (*Oncorhynchus kisutch*) salmon in the Big Qualicum River, British Columbia. Journal of Fisheries Reserve Board of Canada 27:1215-1224.

Lister, D.B., C.E. Walker, and M.A. Giles. 1971. Cowichan River chinook salmon escapements and juvenile production 1965-1967. Fish. Serv. (Can.) Pac. Reg. Tech. Rep. 1971-3:8 p.

Loudermilk, W.E., W.G. Neillands, S.J. Baumgartner, J.S. Kleinfelter. 1995. San Joaquin River chinook salmon enhancement project. Annual Report, Fiscal year 1990-91. Study Number 5, Jobs 1 through 7. CDFG Region 4, Fresno, CA.

Mains, E.M., and J.M. Smith. 1964. The distribution, size, time, and current preferences of seaward migrant chinook salmon in the Columbia and Snake Rivers. Wash. Dep. Fish. Fish. Res. Pap. 2(3):5-43.

Miner, J.G., and R.A. Stein. 1996. Detection of predators and habitat choice by small bluegills: effects of turbidity and alternative prey. Transactions of the American Fisheries Society 125:97-103.

Moyle, P.B. 1976. Inland Fishes of California. University of California Press, Berkeley.

Murphy, M.L., J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. Habitat utilization by juvenile Pacific salmon in the glacial Taku River, southeast Alaska. Pages 335-336.

Piper, R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D.C.

Reimers, P.E. 1971. The length of residence of juvenile fall chinook salmon in Sixes River, Oregon. Ph.D. thesis. Oregon State University, Corvallis, OR. 99p.

Roper, B.B., and D.L. Scarnecchia. 1999. Emigration of age-0 chinook salmon (Oncorhynchus tshawytscha) smolts from the upper South Umpqua River basin, Oregon, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 56:939-946.

Schoettger, R.A. and E.W. Steucke. 1970. Synergic mixtures of MS-222 and quinaldine as anesthetics for rainbow trout and northern pike. The Progressive Fish-Culturist. Oct. 1970:202-205

Sommani, P. 1972. A study on the population dynamics of striped bass in the San Francisco Bay Estuary. Dissertation, University of Washington.

Wootton, R.J. 1990. Ecology of Teleost Fishes. Chapman and Hall. New York, N.Y.

Yoshiyama, R.M., F.W. Fisher, and P.B. Moyle. 1998. Historical abundance and decline of chinook salmon in the central valley region of California. North American Fisheries Management 18:487-521.

APPENDICIES